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PINEY ANALYSIS AREA
HOLY CROSS RANGER DISTRICT
WHITE RIVER NATIONAL FOREST

FOREST HEALTH ASSESSMENT

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EXECUTIVE SUMMARY

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WHITE RIVER NATIONAL FOREST
FOREST HEALTH ASSESSMENT

At the request of the White River National Forest and the Holy Cross Ranger District, the forest health of the Piney River/Red Sandstone Area was examined. Because of the history of mountain pine beetle (*Dendroctonus ponderosae*) activity in the lodgepole pine cover type, that forest component was chosen for detailed evaluation. However, some attention was also given to the impacts of spruce beetle (*Dendroctonus rufipennis*) in the spruce-fir cover type.

Analysis of existing stand exam data revealed that the greatest potential threat to the stands of the lodgepole pine cover type was from three different mortality agents: mountain pine beetle, lodgepole pine dwarf mistletoe (*Arceuthobium americanum*), and Armillaria root disease (*Armillaria spp.*). Once these major impacts upon the forest ecosystem were identified, a systematic survey was performed in which 20% of the lodgepole pine stands in the analysis area were examined. Although the survey data from 1994 yielded information similar to that which was gleaned from a combination of the 1994 and pre-1994 inventory data, greater confidence is given to the "1994-only" data set. In addition, the 1994 survey contained information on root disease intensity and occurrence, whereas the pre-1994 data did not. Data from both the old and new stand examinations, together with information gleaned from computer projections of future insect and disease trends, have been incorporated into this document which covers the biology of the four major pests, addresses their impacts on the Piney Analysis Area, and presents a number of management options to mitigate their effects.

Through this analysis, the following conclusions were reached:

- The potential impacts of insects and diseases should be considered in all silvicultural decisions that are made in the Analysis Area.

- Currently, most major forest vegetation types in the Analysis Area differ markedly in structure from the desired forest condition as defined in the Land and Resource Management Plan for the White River National Forest. Most of these vegetation types have more than 50% of their structural stages in mature/overmature classes that are conducive to outbreaks of most of the important insect and disease agents. This situation has largely come about as a result of the fire suppression that has been practiced on the Forest for most of this century, interrupting the natural disturbance regime which helps maintain ecosystem health. Without the widespread

implementation of corrective treatments, catastrophic fires and major insect and disease outbreaks are almost certain to occur.

- The Analysis Area is at risk for a substantial mountain pine beetle outbreak. Silvicultural treatment efforts to reduce bark beetle risk levels, which were initiated in 1984, have failed to keep pace with what is needed. At the present time, approximately 96% of the acres in the lodgepole pine cover type are at a moderate to high risk levels (25% high, 71% moderate). Most stands that fell into the high and moderate risk classes have age and structural characteristics that are highly conducive to bark beetle attack. Elevation was most responsible for differentiating between the high and moderate-risk stands.

  Because of the recurring, cyclical nature of mountain pine beetle outbreaks, it is no longer a matter of <u>if</u> a major outbreak will occur, but <u>when</u> it will occur. Controlling tree density over large acreages is the only feasible way to reduce the beetle risk. Recommended treatments include clearcutting, selective thinnings and the use of prescribed fire. In areas below 10,400 feet in elevation, stocking should be reduced to a maximum of 120 square feet of basal area per acre. Fortunately, 95% of the lodgepole pine sites covered in the assessment occur on slopes that are less than or equal to 40%, and can therefore be harvested using mechanized equipment. Specific treatment strategies will need to be chosen on the basis of specific on-the-ground situations.

- At least 80% of the spruce/fir acreage in the Piney Analysis Area is at moderate to high risk to spruce beetle loss. The opportunistic nature of the spruce beetle requires that managers be vigilant regarding potential outbreaks of this insect. Areas of windthrow, where extensive spruce slash has been created, as well as areas of large spruce in well drained creek bottoms should be monitored for sign of the insect. Aerial surveys can aid in this effort. Once populations are detected, prompt action will be required to remove beetles by sanitation salvage of infested trees.

- While lodgepole pine dwarf mistletoe is widespread throughout the Analysis Area, it is less prevalent than on the White River NF as a whole. However, a number of stands should probably be scheduled for treatment. Patch-cutting, clearcutting, shelterwood or seed tree cutting remain the only viable treatment alternatives where stand dwarf mistletoe ratings (DMRs) are moderate to high. Below this level, sanitation thinning may be considered. Controlled burning may also be used to sanitize stands, but any live residual infected trees left after the burn must be removed in a timely manner. The particular treatment to be applied must be determined on a case-by-case basis, according to the individual stand conditions and the intensity and distribution of the dwarf mistletoe infestation. The acres that were surveyed at the Piney Analysis Area were rated for dwarf mistletoe infection (DMI) levels, which are always higher than DMR levels. 13% of the acres surveyed had moderate to high DMIs, but since DMI ratings are always higher, this figure should be considered as the absolute maximum of acres on which sanitation thinning may not be applied.

- Approximately 18% of the acres have both dwarf mistletoe (Low, Moderate or High levels) and mountain pine beetle (Moderate to High risk levels) management concerns. Because bark beetle risk may be elevated in mistletoe-infested stands, treatment of moderate to high mountain pine beetle risk stands with dwarf mistletoe is thus a higher priority than treatment of similar mountain pine beetle risk stands without mistletoe. In many of these areas, treatments aimed at reducing bark beetle risk and measures to mitigate the effects of dwarf mistletoe may be combined into a single integrated treatment.

- Armillaria root disease may be found in over half of the lodgepole pine stands in the Piney Analysis Area. Active treatment options, such as patch-cutting, the installation of buffer strips, and the favoring of more tolerant tree species do exist. However, in most cases, the potential impacts of the disease in lodgepole pine will likely not justify the costs of treatment (in the spruce-fir cover type, the situation is quite different). *Armillaria spp.* tends to act only as a thinning agent in younger lodgepole pines, so active management need only be considered in areas where regeneration is inadequate, where other susceptible species are dying, or in the few cases where older lodgepole pines are dying. Monitoring of areas known to contain the root disease fungus is recommended, particularly in areas with high bark beetle risk.

- Although approximately 54% of the acres in the Analysis Area have both Armillaria root disease (High, Moderate or Low levels) and moderate to high bark beetle risk, only 20% have both moderate to high ratings for both. Because root disease centers often serve as foci for bark beetle attacks, treatments to address mountain pine beetle risk should be given a higher priority in root diseased stands.

- Approximately 10% of the surveyed acres have both dwarf mistletoe and root disease, but only 2% have moderate or high levels for both pathogens. Unless root disease is causing unacceptable losses, dwarf mistletoe management should be the driving force for management in these areas. Root disease treatments, if desired, may be easily coordinated with dwarf mistletoe treatments.

- In general, silvicultural and controlled burning treatments, applied on a widespread scale, will provide the most durable, long-lasting solution to the forest health situations in the Piney Analysis Area. The available treatment options summarized above are discussed in detail in the evaluation. The relative effectiveness of these options are summarized in Table 15.

- Prioritization of areas for treatment must take into account the insect and disease conditions of individual stands. Treatment of groups of stands may then be integrated to make sense at appropriate watershed or landscape levels. Highest treatment priority should be given to stands with the highest levels of mountain pine beetle risk and/or dwarf mistletoe incidence and severity ratings. Treatment of moderate-to-high mountain pine beetle risk stands that contain dwarf mistletoe should receive higher

priority than similar stands without dwarf mistletoe. Proximity to high value areas, such as campgrounds, recreation areas, or important viewsheds should also be used to determine treatment priority. Armillaria root disease in lodgepole pine need only be considered if mountain pine beetle risk is moderate-to-high, regeneration is inadequate, or if older lodgepole pine or other susceptible species are dying. In areas where root disease and dwarf mistletoe are present, but bark beetle risk is low, dwarf mistletoe will usually be the driving force for decisions regarding management priorities.

- Because of our limited ability to treat large landscapes and restrictive legislation affecting forest management activities, we will likely have to accept many of the major changes that will occur across most areas of the Forest. Small scale disturbance events may result in greater biodiversity and may help in achieving long term forest management goals, whereas large scale events may be catastrophic and unacceptable. While management efforts must be directed toward the avoidance of these catastrophic events, opportunities to improve the health of the forest should be taken wherever possible. The White River National Forest clearly has the administrative direction to proceed with the management actions necessary to address the forest health situation at the Piney Analysis Area. Plans for landscape-level treatment should be developed and implemented as soon as possible.

- The conditions encountered at the Piney Analysis Area are by no means unique. Similar conditions are common throughout the lodgepole pine cover type on the White River National Forest and on other Forests throughout the Rocky Mountain Region. The recommendations given and conclusions reached in this evaluation may easily be applied to many similar areas.

- In 1996 (during the preparation of this document), aerial surveys were conducted over most of the forested areas of Colorado to document ongoing forest insect and disease activity. Fifteen "spots" of ongoing mountain pine beetle activity were identified in mature lodgepole pine in the Piney Analysis Area. Based on this assessment of stand conditions and on observations in immediately adjoining areas, mountain pine beetle activity in the Piney Analysis Area is expected to increase over the next several years.

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A. Introduction and Objectives

Lodgepole pine grows in extensive pure and mixed stands within the Piney Analysis Area. Lodgepole pine is considered a seral species, yet it dominates large areas throughout the Rocky Mountain region. An important component of the lodgepole pine ecosystem are the "change agents" of fire, insects and disease which periodically revert stands to an earlier seral stage and allow the continued predominance of lodgepole pine.

Following settlement of the Summit/Eagle County area in the late 1800's, the extensive stands of lodgepole pine were increasingly viewed as a commodity to be exploited. As a result, widespread outbreaks of mountain pine beetle, *Dendroctonus ponderosae*, which occurred in 1910-1912 and 1944-1945 were noted with some concern by local residents as well as USDA Forest Service personnel.

Although the outbreaks abated with time, by the early 1960's entomologists were noting that stand conditions were becoming increasingly favorable for a beetle outbreak. An evaluation of the area conducted in 1967 by D.A. Hester stated that although pine beetle numbers were currently very low, the large contiguous stands of mature lodgepole pine could lead to a large infestation. He recommended that monitoring of the stands be stepped up, and that all infested trees which were discovered be salvaged, burned or treated with EDB (ethylene dibromide). Although monitoring continued to increase with time, it became impossible to keep up with the slowly increasing number of beetle killed trees.

In 1980, aerial surveys detected increasing mortality of lodgepole pine to the mountain pine beetle on the White River National Forest near the towns of Minturn and Eagle, Colorado. As a result of increasing concern, biological evaluations were conducted on the Holy Cross Ranger District in 1980 (Lister, 1981). It was predicted that the infestation would continue to spread and cause additional tree losses.

As the outbreak developed, additional evaluations were conducted to follow the progress of the infestation on the Holy Cross Ranger District, including the Holy Cross Wilderness, Eagles Nest Wilderness and adjacent private, state and BLM lands (Averill and Lister, 1982; Lister, 1982). The mountain pine beetle was expected to increase on all lands due to the high percentage of highly susceptible lodgepole pine stands. As a result, recommendations were presented to reduce losses.

With the continuation of tree mortality by mountain pine beetle, the Summit-Upper Eagle-Integrated Forest Management (SUE-IFM) Project was initiated in 1982. This was a cooperative project involving the USDA Forest Service, Colorado State Forest Service, Summit and Eagle Counties, local communities and private landowners. The purpose of the project was to manage and control the epidemic on private and federal lands.

On National Forest lands, a combination of treatments were implemented to reduce damage from the ongoing infestation and to reduce the potential for future epidemics. Treatments included direct treatment of infested trees by the application of the chemical ethylene dibromide (EDB) and removal through salvage logging. Silvicultural treatments consisted of regeneration harvesting of susceptible stands, precommercial thinning, and overstory removal. Other prevention methods included the spraying of individual high value trees in campgrounds with carbaryl to prevent beetle attack (Table 1). By 1985, a significant decline in mountain pine beetle populations was noted throughout the SUE-IFM Project area (Lessard, 1985) and the outbreak had subsided. This document also stated:

> "A significant decline in mountain pine beetle populations occurred throughout the High Country Project area in 1985. This decline provides an opportunity to shift management emphasis from suppression to stand management. If the primary goal is the maintenance of the lodgepole pine cover type within the project area, then about 14,000 acres need to be regenerated each decade. If the primary goal is to substantially reduce the susceptibility of the cover type to mountain pine beetle, then about 51,000 acres need to be regenerated each decade."

Note that in the decade of 1984 until 1994 a total of 1,201 acres were regenerated (see Section H- Desired Forest Condition).

In 1991, the Forest Supervisor contacted the Forest Health Management Staff to request an evaluation of previous management activities, to determine the potential for future outbreaks, and make recommendations for the management of susceptible lodgepole pine stands. Other questions to be addressed were:

- Have the treatments employed over the past decade been successful in minimizing resource losses to mountain pine beetle?

- Have localized large-scale treatments within a watershed resulted in unacceptable cumulative impacts to resource values?

- With increased public concern and opposition to clearcutting, will other silvicultural treatments prove equally effective in meeting the objectives of the SUE-IFM Project?

In response to this request, meetings were held in 1992-1993 to develop a strategy for the production of biological assessments to address these questions. The first and third questions fall within the scope of the current analysis. The second requires input from other resource groups, such as wildlife, soils, hydrology and recreation.

It was decided that an area would be selected for analysis that encompassed several thousand acres for which stand exam data existed and vegetation management treatments had been conducted in response to mountain pine beetle outbreaks and dwarf mistletoe

Table 1. Summit-Upper Eagle IFM Project - Summary of treatments (FY 1982-91).

Treatment	No. of trees or acres
Direct treatment of infested trees (EDB treatment-trees)	107,285
Removal of infested trees through timber sales (trees)	80,012
Preventative spraying (carbaryl treatment-trees)	17,438
Regeneration-harvesting (acres)	4,753
Regeneration-harvesting (Public fuelwood-acres)	523
Timber stand improvement (acres)	4,249
Dwarf mistletoe control (acres)	994
Silvicultural stand exams (acres)	152,571

infestation. The area selected was the Piney River/Red Sandstone area, which encompasses three watersheds over more than 85,000 acres of which 48,000 acres are forested (Figures 1-2). Approximately 31 percent of the area is classified as lodgepole pine type (15,000 acres) and a detailed analysis would be concentrated on that component. This evaluation, therefore, concentrates on the lodgepole pine cover type of the Piney Analysis Area, though, at the request of the Forest, some attention is also given to the impacts of spruce beetle in the spruce-fir cover type.

B. Ecology of the Major Forest Insects and Diseases on the White River National Forest

The White River National Forest includes more than 1.4 million acres of forested lands in Colorado. The forests that we see today have been shaped over the millenia by natural events including fire, insects and disease. In the past few thousand years, native Americans used fire to clear areas for game, however, their impact was not as obvious as that of modern man. In more recent history, the forest has been impacted by mining and settlement.

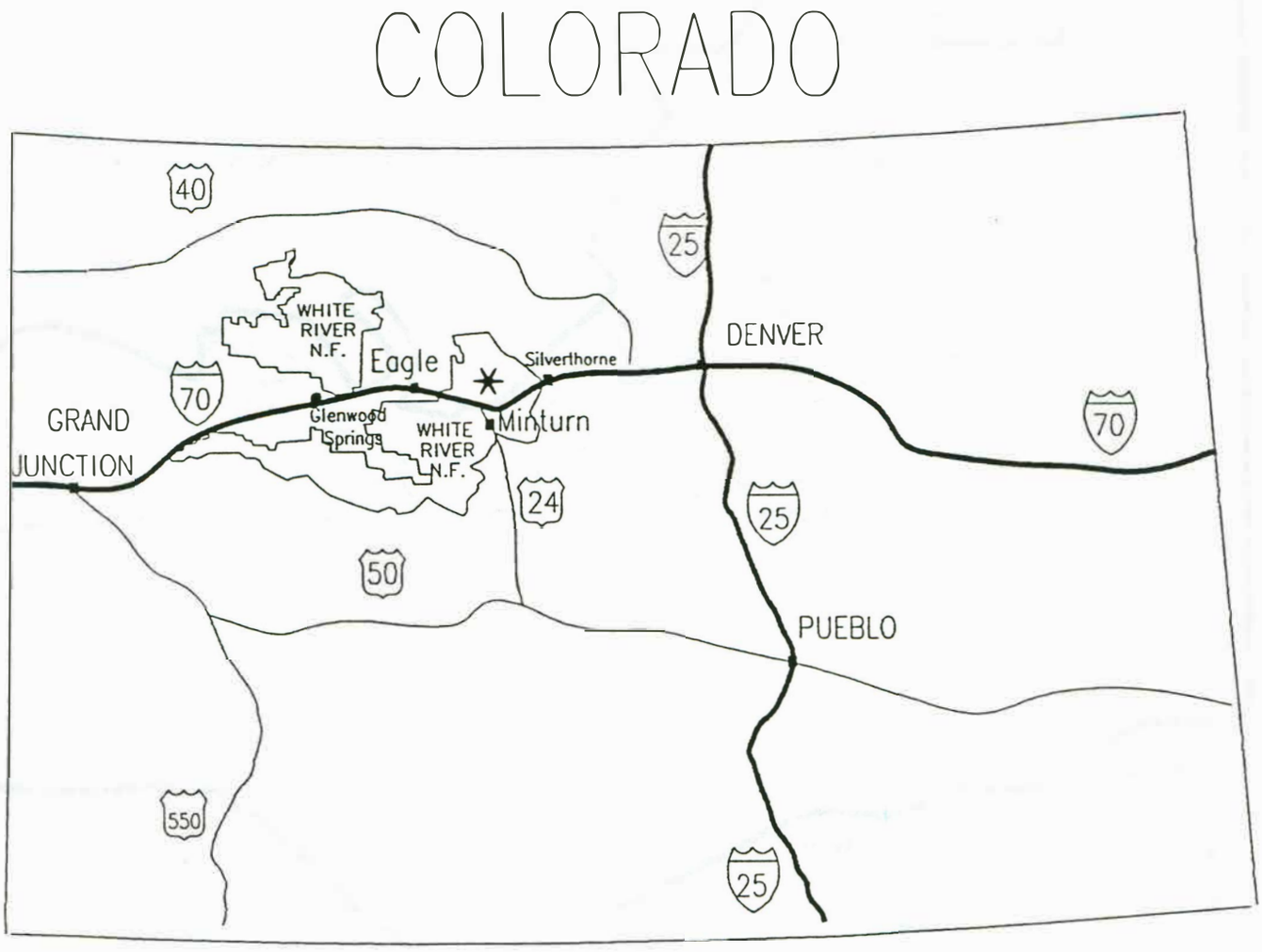
Inventories show that the Engelmann spruce/subalpine fir (*Picea engelmanniilAbies bifolia*) forest type is most common on the Forest followed by aspen (*Populus tremuloides*), lodgepole pine (*Pinus contorta*), and Douglas-fir (*Pseudotsuga menziesii*) (Table 2). Most of these stands are mature to overmature, in fact, about 60 percent of the stands are in this condition (Table 2). With the majority of the forested lands in a mature to overmature condition, fire, insects and disease will continue to be significant natural factors in forest ecology in the future despite the presence of man.

Of the numerous insects and diseases that affect forests, only a few have had a significant impact on the attainment of forest management objectives and will be discussed in detail. Major infestations of spruce beetle (*Dendroctonus rufipennis*) and mountain pine beetle (*D. ponderosae*) have caused mortality over large areas of the Forest in the past and continue to play a role in forest succession. The most important diseases are caused by the dwarf mistletoes (*Arceuthobium spp.*) and root diseases (*Armillaria spp.*). This section will focus on the role of these organisms in the forest.

Spruce Beetle

The tree killing potential of the spruce beetle has been well documented during the last 100 years. This insect infests all species of spruce in North America. On the White River National Forest, Engelmann spruce is the principal host. Spruce beetles generally prefer to attack green windthrown or other recently downed spruce. As a result, endemic beetle populations are always present, breeding in scattered down material, in the spruce-fir forest type. Outbreaks begin after a major forest disturbance (e.g., a large windthrow)

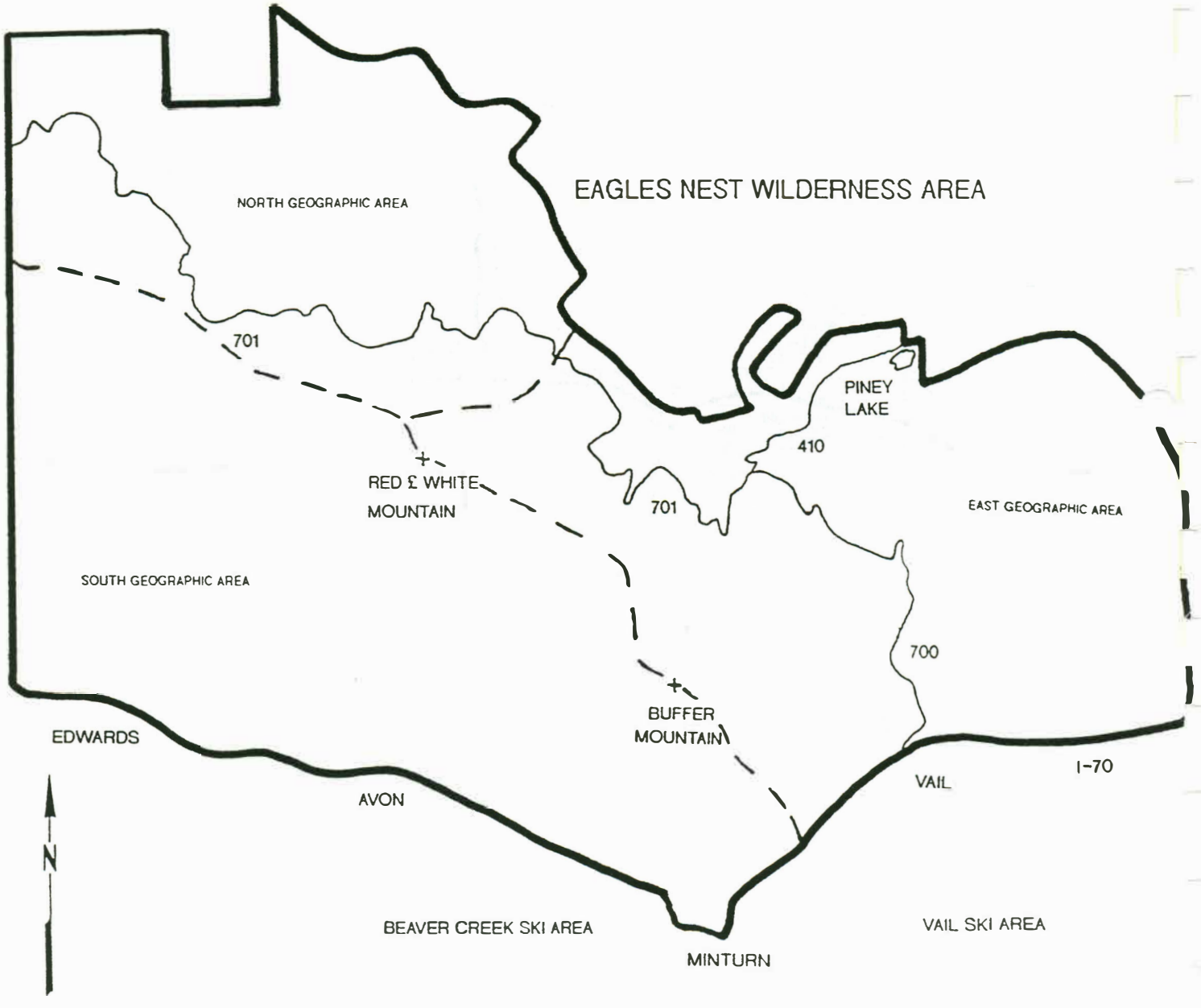
FIGURE 1
VICINITY MAP



*PINEY BIOLOGICAL EVALUATION

FIGURE 2
PINEY BIOLOGICAL EVALUATION

Project Area Map



SCALE 1/2 inch = 1 mile

Table 2. Major forest types on the White River National Forest and condition.

Forest type	Acres [1/]	Acres mature/overmature	Percent
Spruce/fir [2/]	685,571	342,785	50
Aspen [3/]	439,155	254,710	58
Lodgepole pine [3/]	257,977	234,760	91
Douglas-fir [2/]	63,141	25,260	40
Totals	1,445,844	857,515	60

1/ Source of data: USDA Forest Service 1987. Inventory of National Forest System lands administered by Region 2. Book 3 Forest and regional area x age class curves. Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region.

2/ Classified as mature/overmature if 120 years or older.

3/ Classified as mature/overmature if 80 years or older.

creates an abundance of suitable breeding material. Beetle populations rapidly increase in the down material and then readily attack standing spruce. Outbreaks may persist until suitable host material is depleted. The susceptibility of a stand to spruce beetle outbreaks is dependent on:

- The physiographic location of the stand.
- The average diameter of the spruce in the stand.
- The basal area of the stand.
- The proportion of spruce in the canopy.

In general, spruce stands on well-drained creek bottoms having large diameter spruce, high basal areas, and high proportions of spruce in the canopy are susceptible to outbreaks (Schmid and Frye, 1976).

Spruce beetle outbreaks on the White River National Forest

Tree ring evidence suggests that the earliest known spruce beetle outbreak on the White River Plateau occurred in the early 1700's (Miller, 1970; Veblen, 1993). In the mid 1870's, Sudworth (1900) found that 10-25 percent of the mature spruce on the White River Plateau and the Grand Mesa were dead. Hopkins (1909) later confirmed that the spruce beetle was the cause of this mortality. Photographic and tree-ring analysis by Baker and Veblen (1990) suggest that the mortality observed by Sudworth and Hopkins occurred between the 1850's and 1880's and affected forests from central New Mexico to north-central Colorado.

In the 1940's, the White River National Forest, Arapaho National Forest, Grand Mesa National Forest, Routt National Forest, San Juan National Forest, and the Uncompahgre National Forest were the sites of the most damaging spruce beetle outbreak ever recorded (Massey and Wygant, 1954). In the White River National Forest, more than 700,000 acres were devastated by the beetle (Hinds et al., 1965). This outbreak was triggered when, in 1939, a violent windstorm blew down extensive patches of subalpine forests in western Colorado (Hinds et al., 1965). The White River Plateau suffered the greatest spruce losses during this outbreak with most of the spruce mortality occurring between 1943 and 1946 (Hinds et al., 1965). By the time the outbreak subsided in 1952, nearly all spruce 8 inches in diameter and larger on the plateau, an estimated 3.8 billion board feet of timber, were killed (Massey and Wygant, 1954; Hinds et al., 1965). Today, many of the spruce killed during this outbreak remain standing and the severity of the outbreak is still evident.

Although the major spruce beetle outbreaks listed above have caused significant changes in stand structure over extensive areas, not all epidemics create these extreme effects. More common are epidemics of lesser magnitude which may kill 10 to 20 percent of the stand or only the largest diameter trees within the stand (Frye and Flake, 1972).

The most significant forest responses to the 1940's outbreak were the shift in species composition from 90 percent spruce - 10 percent fir to 20 percent spruce - 80 percent fir and the release of previously suppressed fir and spruce (Schmid and Hinds, 1974; Veblen et al., 1991). If the outbreak favored establishment of new spruce and fir seedlings, this effect was not evident approximately 40 years later (Veblen et al., 1991). Because fir is more abundant than spruce in the understory, in areas susceptible to spruce beetle outbreaks, more of the former species can be expected to grow into the larger size classes following an outbreak (Peet, 1981; Veblen, 1986). However, given the greater longevity of spruce, stands that have experienced a spruce beetle outbreak will continue to be codominated by both tree species.

Spruce beetle outbreaks may have long-term effects on ungulate populations. Yeager and Riordan (1953) found that the killing of the stands initially improves the summer forage for deer and elk. However, increasing numbers of fallen dead trees may inhibit the movement of ungulates for many decades following the outbreak. Hinds et al. (1965) found that 25 percent of the beetle-killed trees were windthrown 20 years after an outbreak.

Beetle-killed spruce become hazards for recreationists because trees decay and fall or become windthrown before decaying. The increased windthrow is also a concern to recreation managers who must contend with increased trail and campground maintenance costs.

Spruce beetle outbreaks create a large fuel source for fires. Much of the area affected by the 1940's outbreak has greater than 100 tons of dead fuel per acre (Leighty, 1993). Decomposition of the dead trees is slow because of the slow rate at which the trees fall and the fact that many of the trees fall atop each other and do not contact the ground for several decades. Although heavy fuel loading means that fires in this area would be catastrophic and difficult to control, natural ignitions in the spruce-fir forests of the White River Plateau are rare due to the generally moist environment during much of the fire season.

Mountain Pine Beetle

The mountain pine beetle is a native bark beetle that has had a persistent outbreak history in the mature and over-mature lodgepole pine stands of the White River National Forest. The large scale mountain pine beetle epidemics of the 1980's provide an example of natural forces causing large scale changes in spacing and age class distribution as well as accumulation of dead biomass. Most epidemics develop as a direct result of stand history; unmanaged stands that are highly stocked with large numbers of mature and overmature lodgepole pine are particularly susceptible (McGregor et al., 1985).

The mountain pine beetle usually infests standing live trees larger than eight inches in diameter, but may attack smaller trees when intermixed with the larger trees. During

epidemics, trees are usually killed in small groups of 3-10 trees but such groups may coalesce into one large group of more than 100 dead trees. Endemic mountain pine beetle populations are usually associated with single trees which are diseased or stressed by any number of agents or causes. The susceptibility of lodgepole pine stands to outbreaks can be estimated by average tree diameter, average tree age, and location by elevation and latitude (Amman et al., 1977).

In order to be susceptible to a beetle epidemic, a lodgepole pine stand must be located at an elevation and latitude where climate is favorable to the beetle. A general model for determining if a stand lies within a zone of potentially heavy, moderate, or light beetle infestation is presented by Amman et al. (1977). In general, stand age must be 80 years or more, and the average d.b.h. of a stand for trees 5 inches and larger must exceed 8 inches. By multiplying the risk factors (1=low; 2=moderate; 3=high) for elevation and latitude, average age, and average d.b.h., the stand's susceptibility classification is obtained; low=1-9; moderate=12-18; high=27. This scheme is presented below:

Elevation (feet) [1/]		**Average age (years)**		**Average d.b.h. (inches)**	
> 10,400	(1)	<60	(1)	<7	(1)
9,400-10,400	(2)	60-80	(2)	7-8	(2)
< 9,400	(3)	>80	(3)	>8	(3)

1/ Elevational risk values vary according to latitude. Values given are for the White River National Forest.

Two of the factors utilized to predict stand susceptibility to mountain pine beetle attack, average age and average d.b.h., increase as time passes, thus increasing susceptibility. As a result, if average stand age and average diameter are not altered by management activities or natural disturbance, stand susceptibility inevitably increases over time. On the White River National Forest, fire exclusion has altered stand conditions to favor outbreak of the beetle. However, mountain pine beetle populations are currently in endemic status on the Forest.

The mountain pine beetle influences stand structure in pure pine stands. During an epidemic, mountain pine beetle kills greater portions of large diameter trees, so the average stand diameter is lowered. Depending on the extent of the tree killing within the stand, small to large openings may be created in the canopy. Under extreme epidemics, entire stands may be killed so the site is thus converted to a younger age class of pine or to another seral stage.

mountain pine beetle epidemics also influence herbage production, wildlife populations, and fire hazard. The growth of forbs and grasses increases in beetle-killed areas. Wild ungulates may benefit from the increased herbaceous production and the standing beetle-

killed trees may provide habitat for cavity nesting birds. In general, the influence of mountain pine beetle epidemics will vary depending on the needs of the particular species. Fire hazard is increased for several years following mountain pine beetle mortality due to the dead needles remaining on the trees and the probability of higher intensity fires may be increased for a number of years as the dead trees fall to the ground and add to the surface fuel loading.

The frequency of mountain pine beetle epidemics in a given area may range from 20-40 years depending how rapidly some trees grow into large diameter categories. However, for a given stand, the frequency between epidemics may range from 50-100 years depending on how much of the original stand was beetle-killed.

Many factors are responsible for initiation of a bark beetle outbreak. The condition of potential host stands is very important, the trees must be of sufficient size and numbers to sustain an outbreak. Additional stress factors such as drought, lightning strike or wind damage may contribute greatly to stand susceptibility and are frequently implicated in beetle outbreaks. Another important consideration is the status of the beetle population itself. Bark beetles are subject to a number of mortality factors which include parasites, predators and disease. A bark beetle population which is experiencing heavy mortality due to some agent is unlikely to develop into an outbreak situation.

Considering the many factors which must be favorable for an outbreak to occur, it is almost remarkable that they happen at all. However, the reproductive potential of bark beetles combined with an efficient means of locating and utilizing susceptible trees make bark beetle outbreaks an all too frequent event. Ultimately, bark beetle outbreaks are caused by a convergence of favorable conditions. Since an outbreak is the result of a number of different factors, it is impossible to predict the timing of an outbreak. Susceptibility analysis or risk rating reveals only a stand's propensity for being attacked and can give no inference with regard to exactly when or where it will occur. For this reason, manipulating stand conditions to resist beetle attack is usually the most efficient means of management.

Lodgepole Pine Dwarf Mistletoe

The dwarf mistletoes are parasitic seed plants that affect most conifers in the western United States. Dwarf mistletoes and western conifers began evolving together about 25 million years ago. Today, the dwarf mistletoes are one of the most widespread and damaging groups of forest diseases in the West. Fires normally change forest composition and sanitize infested stands by killing the parasite when the host tree is killed. The new replacement forests are essentially free of mistletoes where large fires occurred. Thus, almost half a century of fire suppression of large fires has also played a critical role in shaping these forests.

In the absence of fire and management, however, the status of dwarf mistletoes does not change markedly from year to year. Mistletoes spread slowly, at a rate that averages one to two feet per year in even-aged (single cohort) stands. Past management practices have, in some situations, increased the rate of spread of the disease by the perpetuation of unevenaged stand conditions that accentuate the spread of dwarf mistletoe from overstory to understory trees. The incomplete removal of infected trees, usually non-merchantable, in timber sale areas has led to increased spread of the disease. The retention of infected trees along visual corridors and for wildlife habitat has resulted in subsequent spread to adjacent uninfested stands. The limitations on the size of harvest units in recent years has also had an impact. It is most effective to cut all infected trees in stands of at least 20 acres in extent to minimize reinfection from the edges of the stand. Small harvest units can aggravate and intensify the rate of infection. The lack of markets for smaller trees that occur in heavily infested, low volume stands has also prevented treatment of many diseased stands.

Silvicultural practices to control dwarf mistletoes have been advocated since the early part of the century; however, these efforts were limited to removing only the large, merchantable overstory trees during the course of harvesting operations. This type of partial cutting actually increased the amount of infection in residual stands. Leaving infected trees of no commercial value in regeneration areas also intensified the problem.

Forest roads and timber markets began improving in the 1950's. Improved access and markets, coupled with more specific guidelines from research, made it possible for managers to take more effective action against the dwarf mistletoes.

In the past two decades, dwarf mistletoe control programs have been more consistent. In addition, thousands of acres are treated each year through scheduled stand improvement and timber harvesting operations. Despite these efforts, our ability to substantially improve the health of the forest is limited by markets and politics.

Impacts of dwarf mistletoe on the resource

The most important effect of dwarf mistletoes is volume reduction. When trees are heavily infested, dwarf mistletoes reduce both height and diameter growth and increase mortality. The extent of loss depends upon several factors including host and mistletoe species, intensity of infection, site index, stand density and stand structure. Infestation levels vary greatly from stand to stand dependent primarily upon fire history of the stand and past management practices. Significant reduction in yields of stands occurs if they are infected early in their development and if no suppression measures are taken to reduce spread and intensity of the disease.

The first symptom of infection on an individual tree is a swelling of host tissues. Later, the swellings enlarge and produce dense masses of distorted branches called witches' brooms. As the parasite spreads through the tree crown, tree growth is gradually reduced. Eventually the top weakens and dies, diameter growth ceases, and the entire tree dies.

Insects, particularly bark beetles, may cause an earlier death by attacking weakened, heavily infected trees (Johnson et al., 1976). Other pests, such as decay fungi, enter wounds and swellings created by the mistletoes.

Dwarf mistletoes not only cause losses in timber values, but also adversely affect recreation values by killing trees in campgrounds, picnic areas, etc. In addition, the decay and canker fungi associated with dwarf mistletoe infections kill or weaken branches so that they are more susceptible to wind breakage, thus increasing the hazard to recreationists.

Although the debilitating effects of the mistletoes on tree growth and forest productivity are well-documented, their effects on non-commodity forest values have not been fully assessed. The effects on wildlife, for example, may be positive or negative depending upon the particular ecological needs of the wildlife species. Dead trees provide nesting sites for snag-dependent bird species. Witches' brooms also provide cover and nesting sites for many birds and mammals. Large areas infested with mistletoes have a more irregular, open forest canopy, favoring certain bird and mammals species. As the openings regenerate to either the same tree species or other tree species and brush, greater vegetation diversity will occur. This results in profound changes in both stand structure and species composition. The mistletoe plants themselves provide a food source for some mammals, birds and insects.

The impacts of dwarf mistletoes on visual quality would generally be considered negative through reduced tree vigor, increased mortality, and increased fuel accumulations and susceptibility to fire. Effects on other resource values are, for the most part, unknown.

Surveys conducted in 1979 indicate that 36 percent of the lodgepole pine type (52,000 acres) on the White River National Forest is infested with *A. **americanum*** (Johnson et al., 1980). A conservative estimate of merchantable volume loss is more than 31,000 cubic feet per year. Since 1981, more than 14,000 acres have been surveyed and 2,600 acres treated with Forest Pest Management (FPM) funds (Table 3)(Johnson, 1986). This summary only includes projects in which FPM was directly involved. Many more acres of control were accomplished through timber harvests and other stand entries, however, we have no record of the acres treated. The FPM program consists of presuppression surveys, overstory removal, thinning and sanitation, and stand replacement. Since 1980, the program has received greater support and emphasis. Five year planning documents have been prepared and activities and funding requests have been integrated into the Forest planning and budgeting process. This strategy has insured a more continuous source of funding and program continuation than in the past, also resource managers can more effectively schedule time, resources and manpower.

The emphasis of the program in the Region has been on locating and defining those management units where infected non-merchantable overstory trees were left standing in older timber sale areas and pose a threat to established regeneration. In many cases, these young stands will not reach merchantable size if the infected residual trees are not felled or removed.

Table 3. Summary of dwarf mistletoe program expenditures and accomplishments for the White River National Forest - 1981-1995.

Fiscal Year	FPM $		Acres surveyed	Acres treated	
1981	15,900		4,000	--	
1982	20,400		3,000	120	
1983	--	(123,000) [1/]	--	--	(1,300) [1/]
1984	12,000		1,700	110	
1985	13,500		--	130	
1986	11,500		--	90	
1987	19,300		--	179	
1988	67,000		652	476	
1989	34,960 [2/]		854	353	
1990	31,240		796	381	
1991	21,800		1,313	150	
1992	20,600 [3/]		426	164	
1993	24,900		232	201	
1994	35,500		1,043	166	
1995	9,763		--	80	
Totals	290,803	(123,000) [1/]	14,016	2,600	(1,300) [1/]

1/ Figures in parentheses funded by the Jobs Bill.
2/ Includes carryover funds of $26,960 from FY'80.
3/ Includes carryover funds of $20,600 from FY'91.

Armillaria Root Disease

Root diseases are one of the most damaging classes of forest tree diseases in the western United States. These diseases cause economic loss by killing trees, slowing growth, decaying wood, predisposing trees to other harmful pests, causing trees to fail and fall over, preventing reforestation, and reducing stocking levels on regeneration sites.

In an assessment of root disease-caused losses for the western U.S., Smith (1984) estimated average annual volume loss in commercial forest lands at nearly 240 million cubic feet. This loss is approximately 18 percent of the total softwood mortality reported for the West.

Investigations of root disease losses in the Rocky Mountain Region are in their infancy (Johnson, 1984); therefore no data are available on volume loss. Although study plots have been established throughout the Region to monitor disease development in various host types, no loss estimates have been generated from this data.

Surveys of root disease on the White River National Forest indicate that Armillaria root disease is the most common and widespread species (James and Gillman, 1980). Tree species susceptibility varies by host species, tree vigor, age, and habitat type. The fungus is commonly observed on lodgepole pine, ponderosa pine and subalpine fir. The fungus has also been recorded on pinyon pine, Engelmann spruce, white fir, aspen, Rocky Mountain juniper, and cottonwoods.

In forest types in which fire has been an important natural factor in determining species composition and stand characteristics, fire suppression may interact with silvicultural management to promote root disease by allowing regeneration of species which are more susceptible to *Armillaria spp.* Fire control associated with selective logging in some of the drier forests in western North America has favored regeneration of Douglas-fir and true fir stands formerly composed predominantly of ponderosa pine, western white pine and western larch, species apparently less susceptible or more tolerant to root disease. Factors that increase stress in trees such as drought and defoliation by insects may also increase the amount of root disease.

Armillaria spp. is a natural component of the microflora of many forests worldwide. It commonly lives as a saprophyte on dead organic material such as old stumps left from logging. It also kills living tissues and utilizes them as a nutrient source. As a consequence of parasitic activity or disturbance such as logging, windthrow, or fire, *Armillaria spp.* may infect large quantities of roots, stumps and other debris on the ground. From stumps it can spread to living hosts by root contacts and rhizomorphs, which are red-brown or black cords of fungal mycelium similar to shoestrings (1-5 mm in diameter), hence the common name shoestring root rot. Rhizomorphs can grow through

the soil from the food base to the roots of living trees. The fungus then spreads from the roots to the root collar and can parasitize and girdle the tree. In late summer during wet periods, the fungus produces mushrooms which are found in clumps near the base of infected trees or stumps.

This root disease is relatively easy to identify. Affected trees show declining growth (especially height), yellowing foliage, stress crop of cones, and small trees often dying in groups (a characteristic of all root diseases). An exudate of resin is found on the trunk near the soil line and often is mixed with the soil at the root collar. Thick, white mycelial fans occur under the bark of roots and around the root collar. Mushrooms may or may not be present, depending upon the time of year and microsite conditions.

Armillaria root disease occurs commonly in association with bark beetle and woodborer attacked and killed trees. A study conducted in the Colorado Front Range showed that 62 percent of mountain pine beetle killed ponderosa pine were also infected by *Armillaria spp.* (Fuller, 1983).

Armillaria root disease is common in cutover lodgepole pine stands that have regenerated naturally (Sharon, 1988). An evaluation of a 31 year old stand on the Poudre Ranger District (Roosevelt National Forest) showed that 12 percent of the cumulative mortality was attributed to this fungus (Johnson and Hawksworth, 1977). However, no disease centers were large enough to result in understocking of the stand. In addition, annual loss of trees over a period of 18 years showed a reduction in tree mortality from nearly 2 percent per annum to less than 0.5 percent.

Surveys of naturally regenerated lodgepole pine seedling-sapling stands in the central Rocky Mountains indicate that up to 11 percent of trees are infected or killed by Armillaria root disease (Sharon, 1988). Disease incidence is not uniform throughout stands. Most diseased trees are located near stumps, which probably served as infection sources. However, as lodgepole pine stands reach 25-30-years old, overall impacts appear to diminish.

C. Management Activities to Reduce Losses to the Major Insects and Diseases

Spruce Beetle

Most spruce beetle outbreaks begin following a large forest disturbance such as blowdown or logging which create abundant breeding sites for beetle populations (Wygant and Lejeune, 1967). The spruce beetle is considered a very opportunistic insect. Unlike mountain pine beetle, which can cause an outbreak in stands of fairly good vigor, spruce beetle requires a source of hosts which have been damaged in some way. Spruce beetle populations increase in weakened host material and eventually spread to adjacent healthy stands.

Spruce beetle outbreaks may be prevented by salvaging windthrown trees within two years, by removing all spruce log decks within two years of logging operations or road construction, by cutting trees as low to the ground as possible to reduce stump height, and by removing or destroying cull logs, tops, and large diameter slash immediately following cutting activities in mature spruce stands. Close monitoring of the forest as a whole combined with a prompt response to the creation of conditions favorable to the spruce beetle goes a long ways towards outbreak prevention.

Where a substantial spruce beetle population already exists in adjacent stands, it may be wiser to leave logging residues rather than to remove or destroy them immediately after cutting (Schmid and Frye, 1977). These residuals will attract beetles from adjacent stands and thereby reduce the number of attacks in standing trees. After the residuals become infested, it is critical that they be removed from the area or burned in a timely manner.

In areas having high spruce beetle populations, living, merchantable-sized spruce may be felled to attract beetles away from living, standing trees. Once these "trap trees" are infested, they can be milled, burned, or chemically treated. Trap trees should be felled between September 1 and October 31. Shaded trap trees will attract more beetles than trap trees exposed to sunlight. Trap trees should be of high quality and the trap tree area should be easily accessible and of sufficient size (10-20 acres) to present a logical logging unit. Trap trees should be removed from the logging area between September 1 and October 31 of the year following their felling.

Both of these methods are highly dependent upon proper timing of treatments. As always, prevention of high spruce beetle populations is the preferable course of action, but "trap logging" can be effective under critical conditions. Application of these techniques should be attempted only with the assistance of a forest health specialist.

Mountain Pine Beetle

A considerable body of literature deals with the control of this insect (Amman et al., 1977; McGregor and Cole, 1985; Smith, 1990). Control of bark beetles can be divided into two basic types: Direct and Indirect. Direct control attempts to directly reduce the beetle population by killing large numbers of the insects. Some techniques include removal, processing, peeling or burning of infested trees or application of chemicals to kill the beetles as they emerge from infested trees. Although there have been extensive direct control programs in the past, their efficacy in the long run is now questioned. The problem is that direct control operations attempt to treat the "symptoms" of an outbreak, i.e. large numbers of dying trees. Even if the outbreak is actually suppressed (and the logistics involved are substantial), the conditions which originally spawned the outbreak still exist. It is usually just a matter of time before the beetle population begins to increase once again due to favorable conditions.

Indirect methods of control attempt to create stand conditions which are less favorable to the beetle. A number of silvicultural options exist which attempt to reduce basal area, average stand diameter and stand density. Patch cuts may be utilized to regenerate dense, mature stands and partial cuttings (also called sanitation thinning) may be used to reduce stand basal area and densities within the stand. Evenaged and unevenaged management systems may be utilized to reduce stand susceptibility (Amman et al., 1989).

Direct control measures still have a place in protection of high value trees near homes and recreation sites, but indirect methods are usually the most economical and efficient in the long run. A byproduct of the application of indirect silvicultural control measures is the creation of a mosaic of various stocking levels, age classes and species mixes. Such a mixture of stand conditions is not only more resistant to mountain pine beetle attack per se, but it also spreads the risk of outbreak among the various stand types.

Selection of a silvicultural method to treat lodgepole pine stands depends on a great many factors including stand conditions, susceptibility to windthrow, risk of potential fire damage and insect and disease susceptibility. In the past, clearcutting was the preferred method for establishing even-aged stands, but increasingly, selection cutting, resulting in uneven-aged stands, has gained importance, especially in situations where continual cover is desired. Utilizing mixed-species stands to reduce susceptibility to mountain pine beetle is also a viable option where associate species are available (Mitchell, 1989). This technique reduces the chance of catastrophic loss to bark beetles by creating a stand condition which is inherently less susceptible to an outbreak. In addition, the inclusion of non-host species reduces the overall risk of loss of the entire stand.

A number of studies have demonstrated the efficacy of thinning as a practical method of long-term outreak prevention (Cole, 1978; Gibson, 1989; Cole, 1989). Several theories exist as to why reduced stocking increases a stand's resistance to beetle attack. In the short run it is believed that a thinned stand has an altered microclimate which is not condusive to beetle attack and spread. As time passes, the trees within a thinned stand increase in vigor and are better able to resist beetle attack (Cole, 1989). Once again, other management objectives are important considerations when deciding which silvicultural technique is to be utilized in a given landscape or stand.

When determining a post-harvest stocking level, one needs to consider when the stand will be entered again. Basal areas of 80 to 120 square feet per acre have proven resistant to beetle activity (Gibson, 1989). However, as noted previously, bark beetle susceptibility within a given stand increases with the passage of time. Stand stocking levels should thus be reduced so that the basal area will be below 120 square feet per acre when the stand is re-entered and treated again. If it is known that a stand will not be treated again for a long period of time, the initial treatment should bring the basal area substantially below the 120 square feet value. However, considerations other than bark beetles alone should be considered when deciding on ultimate stocking goals. For example, potential for windthrow is also an important factor to consider (Alexander, 1986).

Ideally, silvicultural efforts over the long run will seek to establish a mosaic of age classes, stocking levels and species mixes over the landscape. A "patchwork" of varied stand types will eliminate large expanses of susceptible hosts. This overall strategy requires that many silvicultural tools be utilized and that prescriptions vary with stand conditions (Gibson, 1989).

Lodgepole Pine Dwarf Mistletoe

The dwarf mistletoes are most easily and economically treated by silvicultural practices. Several features of these parasites make them ideal candidates for cultural management:

- Dwarf mistletoes require a living host to survive. Once an infected tree or branch is cut, the mistletoe dies. There is no need to destroy the slash.

- Mistletoes are generally host-specific; that is they are usually confined to a single host species or group of closely related species. Immune or lightly infested species can be favored during stand treatments.

- Dwarf mistletoes spread slowly. Seed dispersal from a tall, isolated tree is usually limited to less than 60 feet. In evenaged stands, spread is even more limited, averaging 1 to 2 feet per year.

- Dwarf mistletoes have a long life cycle: mature plants take 4 to 6 years to develop from seeds. This long life cycle means the amount of disease builds slowly. If a stand is properly treated, mistletoe should not be a serious problem in subsequent rotations.

- Infected trees and stands are easy to detect because of the presence of dwarf mistletoe plants, branch and stem swellings, and witches' brooms. Heavily infested stands show decline and mortality.

Presuppression surveys are utilized to define areas in need of treatment. Once the resource manager has located general problem areas, the biological need and effectiveness of proposed suppression projects can be evaluated.

Successful silvicultural techniques have been developed specifically for dwarf mistletoe control. These practices can be easily integrated into planned harvesting and intermediate stand treatments. These strategies are aimed at either prevention or suppression of the disease dependent upon the age of the stand and management objectives. Because it is more effective to prevent mistletoes from becoming established than to eradicate them from infested stands or to replace severely infested stands, the priorities in control programs should be placed on prevention. Prevention can be accomplished by:

- Designing treatment units to take advantage of natural or artificial barriers (such as roads, streams, non-susceptible forests, openings, or meadows) that prevent reinvasion from adjacent infested stands.

- Felling or killing all infected trees before an area is planted or naturally regenerated.

- Using regeneration harvests when logging infested stands. Long, narrow harvest strips should be avoided.

- Regenerating stands with the shelterwood method leaving mistletoe-free or lightly infected residual trees. If infected trees must be retained (for instance, in areas sensitive to visual quality objectives or protection of the site from adverse microsite conditions), they should be killed as soon as the site has regenerated and before the regeneration is 5 feet tall or 10 years old.

- Favoring non-susceptible tree species when regenerating a stand or making intermediate stand entries.

These strategies all reduce the likelihood of dwarf mistletoe spreading into a healthy stand. When a stand is already infested, all infected overstory and selected infected understory trees can be felled. This technique, known as sanitation-thinning, can be applied in lightly infested stands. Crop trees should be disease-free. However, lightly infected trees may be retained to meet minimum stocking guides. Replacing severely infested stands with healthy stands by cutting all infected trees, roller chopping, or prescribed burning and regenerating may be recommended in some instances.

In developed sites and recreation areas, the emphasis of control programs has been to reduce spread from individual infected trees and prolong the life of trees by pruning infected branches. Resistant tree species may be planted in the understory with the eventual removal of the infected overstory trees.

Dwarf mistletoe suppression yields multiple benefits including:

- Dwarf mistletoe infection delays the economic maturity of stands, adversely affecting wood quality and tree seed production. Dwarf mistletoe suppression is necessary to insure increased productivity of stands in the future to meet the increased demand for wood products.

- Dwarf mistletoe suppression is necessary to protect other forestry investments, such as site preparation, tree planting, thinning and timber stand improvement. In addition, dwarf mistletoe control in infested stands prevents spread of the disease to adjacent healthy stands.

- Dwarf mistletoe suppression results in increased productivity per acre and under intensive management results in reduced acreage needed to meet timber targets. In

this manner, we can concentrate harvesting activities on fewer acres at reduced cost. With the trend of withdrawal of forest land from timber production and harvesting, it is imperative that we increase the productivity of the remaining commercial forest stands.

- Dwarf mistletoe suppression reduces the susceptibility of stands to insect attack, particularly bark beetles, windthrow, and natural fires.

- The silvicultural practices developed for dwarf mistletoe suppression have been proven to be very effective and provide control of the disease for the current and subsequent rotations.

What measures or combinations of measures are used should depend upon individual stand conditions including stand age and composition, stand density, number of years to harvest, mistletoe incidence and distribution, and length of time the stand has been infested. Valuable tools-- tree and stand growth models and dwarf mistletoe infection models -- are available to aid the resource manager in simulating yields of infected trees and stands. Yields for a stand can be predicted under various management regimes and compared to no treatment. By comparing outputs and economic analyses of control costs, the manager can choose the best treatment for each infested stand and priority for treatment.

Armillaria Root Disease

At this stage in development of our knowledge of this disease, it is not possible to determine the implications of the disease on timber management practices or other resources. The disease is widespread throughout the Rocky Mountain Region and has been reported on all coniferous species and some hardwoods. It has caused scattered tree mortality and predisposes its host to bark beetle attack and windthrow. It also causes decay in live trees. The disease may pose problems in the future as stands are placed under more intensive management. This has been the case in other regions of the country. On the other hand, activities that increase the vigor of the residual stand, such as thinning, may reduce losses to the disease.

Recognition and removal of root disease infected trees in developed recreation sites is a management concern. Other adverse effects of root diseases include buildup of woody fuels and creation of brood material for bark beetles and subsequent loss of adjacent trees as bark beetle populations increase.

Beneficial effects of root diseases include the creation of natural openings and wildlife habitat and increased diversity of plant species as regeneration of root disease centers occurs. Also most root diseases have a saprophytic life stage that helps to decompose woody debris on the forest floor and in living infected trees creates decay and subsequent habitat for cavity nesting animal species.

Silvicultural treatment of stands consists of one or more of the following measures:

- Promoting stand vigor. The impacts of Armillaria root disease, particularly on more disease-tolerant species such as ponderosa pine, are usually greater on stressed trees. Such stresses include drought, overstocking and impacts from other insects and diseases. Methods of reducing stand stress, such as thinning, will help increase resistance to the disease.

- Silviculturally favoring more resistant or tolerant tree species. In general, ponderosa pine is tolerant to damage by *Armillaria spp*. However, where damage occurs, it may be advisable to encourage a mix of other species, including aspen, spruce, and lodgepole pine.

- Patch-cutting infection centers, including the removal of a 30-50 foot buffer zone. This treatment method is often effective where root disease centers are well-defined (easily visible) and low in number. Removal of host trees in a buffer zone around all visibly infected trees is recommended because susceptible trees around the visible infection center are likely to be infected. A mix of disease-resistant or tolerant tree species should be encouraged in the resulting openings.

- Reducing residual inoculum levels between stand rotations. This is accomplished by mechanically removing residual infected stumps and roots from the ground or by push-felling infected harvest trees. This direct reduction of inoculum levels is expensive and requires careful economic analysis. While these treatments are effective and may be warranted in high value sites and developed recreation areas, the cost is usually prohibitive in all other areas.

- Critically evaluate disease impact to ensure that the level of loss justifies control. The use of the Western Root Disease Model may aid in this effort (Stage et al., 1990). If it is determined that the level of impact does not justify control, closely monitor affected stands.

D. Survey Design

In the summer of 1994, a systematic series of stand surveys was performed to meet the objectives of the Piney Analysis. Because the inventory information needed was similar to that used for the Forest's ongoing forest inventory program, the study adopted Regional procedures so that the information gathered could contribute to the Forest's data needs as well.

The survey was designed as a stratified random sample. Three geographically defined strata (North, South and East) were selected, on the basis of both potential biological differences, and because management and use of the three areas are potentially different (Figure 2). Each geographic stratum was further substratified on the basis of the mountain

pine beetle hazard rating (Low, Moderate and High) and dwarf mistletoe infection (DMI) rating (None, Low, Moderate and High) assigned to each stand. Insect and disease ratings used in the stratification were drawn from Stage 2 stand exam data that had been collected from 1976-1993. DMI ratings are distinguished from the more commonly used DMR (Dwarf Mistletoe Ratings) values in that DMI values only include infected trees in the average rating for a stand. DMI ratings are thus a measure of how seriously infected the infected trees are in a given area. DMI calculations tend to inflate the range of values between stands (DMI is generally greater than DMR), and were thus of greater use in separating out high, moderate and low levels of infestation. Because no information was available about the relative variances or importance of each strata, all were sampled with approximately equal intensity.

The sample size was driven by the available budget: costs were estimated on a per plot basis, and the total number of plots then calculated with the budget available for this phase of the project. The number of plot points per stand were determined by using standard Regional practices, which call for five points per stand up to 50 acres, increasing to ten points for stands of 100 acres or more. Within each stratum (geographic area x hazard ratings), stands to be inventoried were randomly selected from a list of all lodgepole pine stands, using a random number table. Stands were selected independent of size, until the total size of all stands in the sample was at least 20% of the stratum area. A total of 79 stands were chosen for survey.

Cover types of the stands were assigned on the basis of the 1976-1993 Stage 2 survey information or photointerpretation (when Stage 2 survey data were not available). However, after the 1994 survey was completed, lodgepole pine was found not to be the major species in 16 of the stands (<50% of stand basal area in lodgepole pine). Following the protocols of Hagle and Williams (1995), these stands were left in the sample if 10% or more of the stand basal area was in lodgepole pine. As a result, only 2 stands were dropped from the final analysis. The final sample thus consisted of 77 stands (3,218 acres, 455 sample points).

E. Survey Methods

Two types of surveys were conducted for the Piney analysis. The first type which will be referred to as "SE/ID" (for stand exam with insect/disease transect) was the standard Region 2 Stand Exam with several additional data items added. The second type which will be referred to as "ID" (for insect/disease transect) was a less intensive modification of the Stand Exam survey. Examples of all data forms may be found in Appendix A.

For all of the exams, the stand boundaries were drawn on 1990 aerial photographs (approximate scale 1:15,840). The points to be surveyed were pinpricked using a grid to equally space them throughout the stand. The points were pinpricked prior to being taken to the field but not numbered until the crew reached the points.

There were three survey crews of two members each. The crews used USGS quad maps (1:24000) and the aerial photographs to locate a known RP (reference point) to start their survey. Using a photo scale ruler, they determined the distance and azimuth from the RP to the first sample point, first point to second and so on. They used a compass to determine the direction (azimuth) of travel and paced to determine the distance.

SE/ID Exam

After arriving at the first point, the crew determined the BAF (Basal Area Factor) to be used for the stand. The same BAF (10, 20, 30 or 40) was used throughout the stand. Trees determined by prism to be "in the plot" were measured. The fixed plot size for the understory trees was always 1/300 acre.

Starting at North, all trees greater than or equal to 5.0 inches D.B.H. were checked using a prism to determine if they fell within the plot. For each "in" tree, the fields on form R2-2410-7b (Holy Cross District 1994 revision) were completed. The "Standard Specifications for Stand Exam, Regions 2, 3, and 4, January 1993 edition" was used as a guide for valid codes and which fields to complete. After the overstory trees were recorded, the understory trees (all tress less than 5.0 inches D.B.H.) which fell in on the 1/300 acre fixed plot were recorded.

The fields which were added to form R2-2410-7b specifically for this project were "Root Disease", "Bark Beetles", and "Fire Scar Date". If Root Disease was found at a plot, the "Stand Exam Supplemental Form" was also completed. All trees within a 1/5 acre plot were examined for this form.

When all plots within the stand were completed, the crew filled out a "Header Sheet and Stand Sketch Information Form", R2-2410-8 (Holy Cross District 1994 revision) following the directions in the "Standard Specifications Guide". On the front page they drew a map showing the locations of their points and also labeled the point numbers on the back of the aerial photograph. On the back page, notes were made about the stand and its past treatment. Two areas added specifically for this survey were "Root Disease Distribution" and "Root Disease Percentage". The average slope and aspect for the stand were also recorded.

The crew also completed an Old Growth form to determine if the stand met old growth criteria as described in "Old Growth Descriptions for the Major Forest Cover Types in the Rocky Mountain Region " (Mehl, 1992).

The completed data was entered into the Oracle based RMRIS data base (Rocky Mountain Resource Information System) on the Data General and summaries of each stand were obtained through the RMSTAND portion of the program.

ID Exam

The same forms and basic methodology were used in the ID exams except that fewer data fields were completed. The crews visited plots as indicated by points on the aerial photo, determined the correct BAF to use for the stand and determined which trees fell within the plot. They then completed the "DBH", "Tally", "I&D", "Mistletoe", "Root Disease" and "Bark Beetle" columns. The understory 1/300 acre fixed plot was not done. If Root Disease was found, the "Stand Exam Supplemental Form" was completed.

When all plots within the stand were completed, the crew filled out a "Header Sheet and Stand Sketch Information Form" and Old Growth form as in the SE/ID exams.

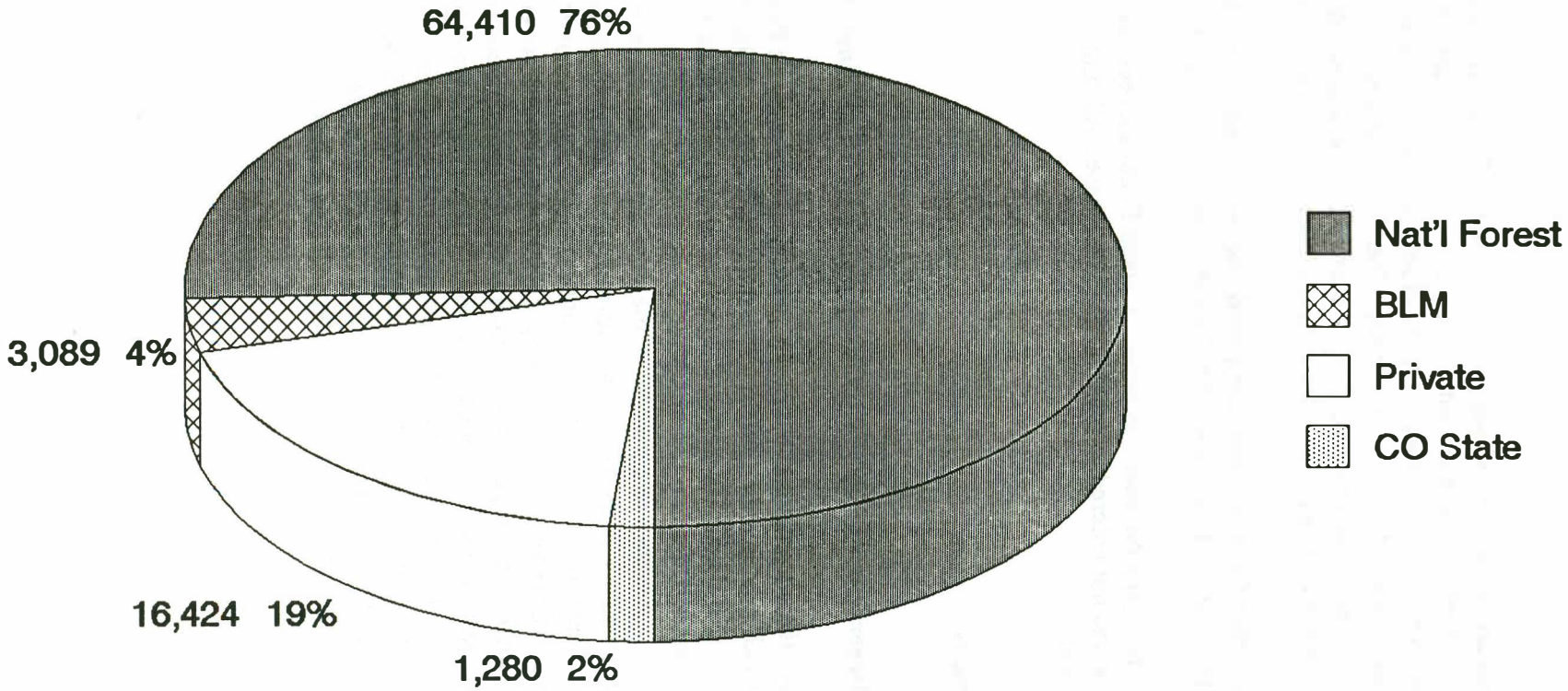
Because this is not complete data and previous Stand Exam surveys exist for all of the ID Exams, the data was not entered into the RMRIS data base. All summary information was calculated by hand.

F. Survey Results

Vegetation, Ownership And Physical Characteristics Of The Piney Analysis Area

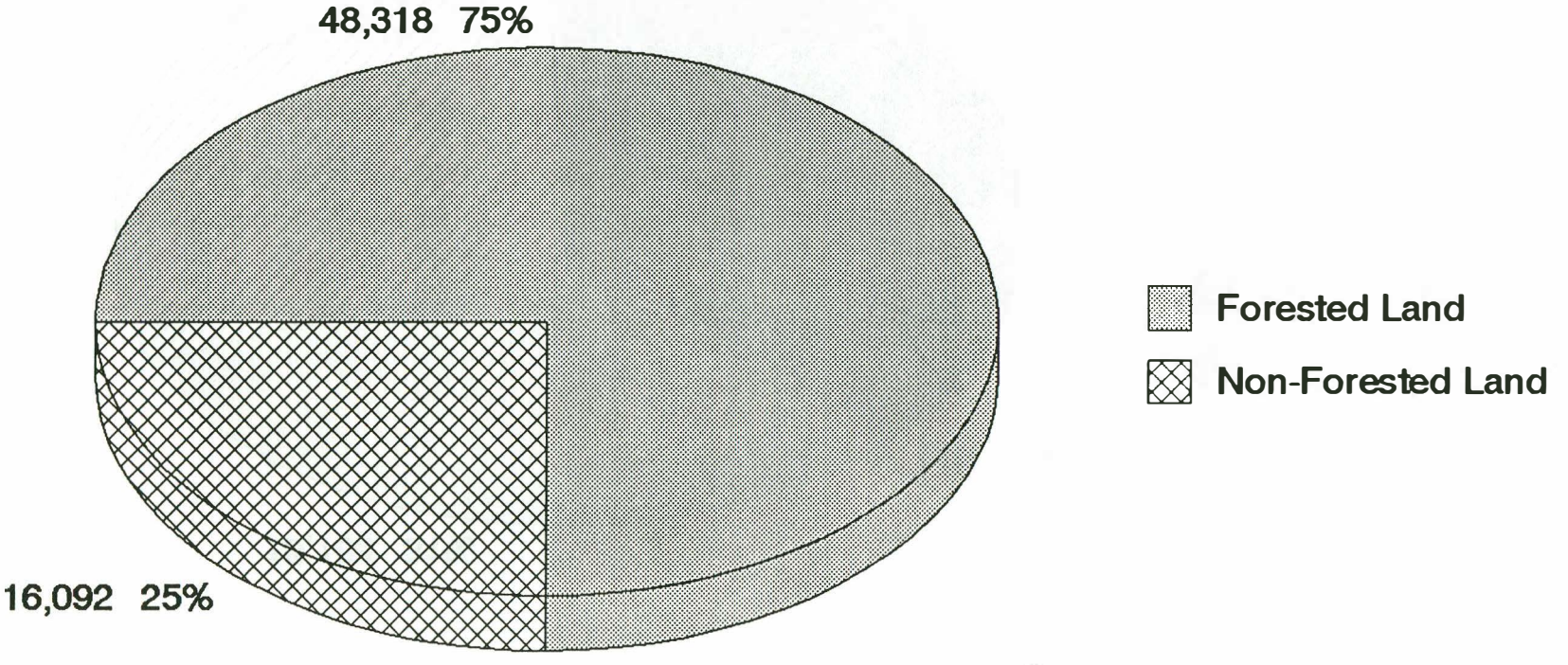
Figures 3-5 show the ownership and cover type patterns of the entire Piney Analysis Area, as determined by all available data (1976-1993 stand examinations, plus the 1994 survey). Seventy-six percent of the 85,203 acres of the analysis area is National Forest land, while the remaining consists of Bureau of Land Management, State and Private lands (4, 2, and 19 %, respectively). Seventy-five percent of the Forest Service land is in forested cover types, while the remaining 25 percent is non-forested (forblands, grasslands, streams, reservoirs, etc.). The forested total, in turn, consists of 36% aspen cover type (17,360 acres), 1% Douglas-fir cover type (601 acres), 31% lodgepole pine cover type (15,184 acres), 31% spruce/fir cover type (14,956 acres) and 0.5% pinyon pine/juniper cover type (217 acres). Age class distributions within the various cover types (except pinyon pine) are shown in Figures 6-9. In addition, ninety-five percent of the lodgepole pine sites covered in the assessment occur on slopes that are less than or equal to 40%, and therefore can be harvested using conventional mechanized equipment. As stated previously, the focus of this evaluation is on the lodgepole pine cover type and, to a lesser extent, the spruce/fir cover type.

Figure 3
Land Ownership within the Piney Analysis Area



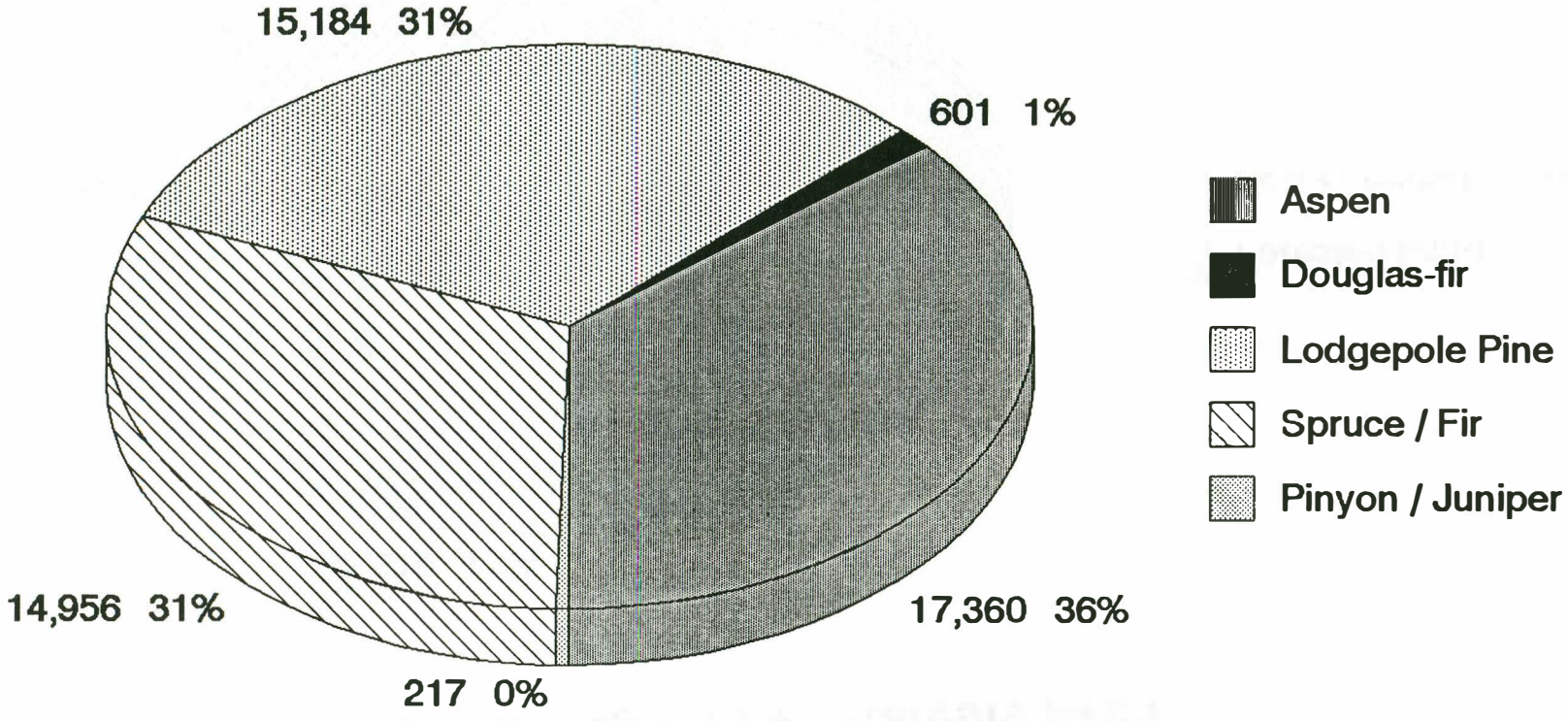
Areas expressed in acres and percent of total

Figure 4
Forested vs. Non-Forested Nat'l Forest Lands within the Piney Analysis Area



Areas expressed in acres and percent of total

Figure 5
Cover Types of the Forested Nat'l Forest Lands within the Piney Analysis Area



Areas expressed in acres and percent of total

Figure 6
Age Class Distribution within the Lodgepole Pine Cover Type of the Piney Analysis Area

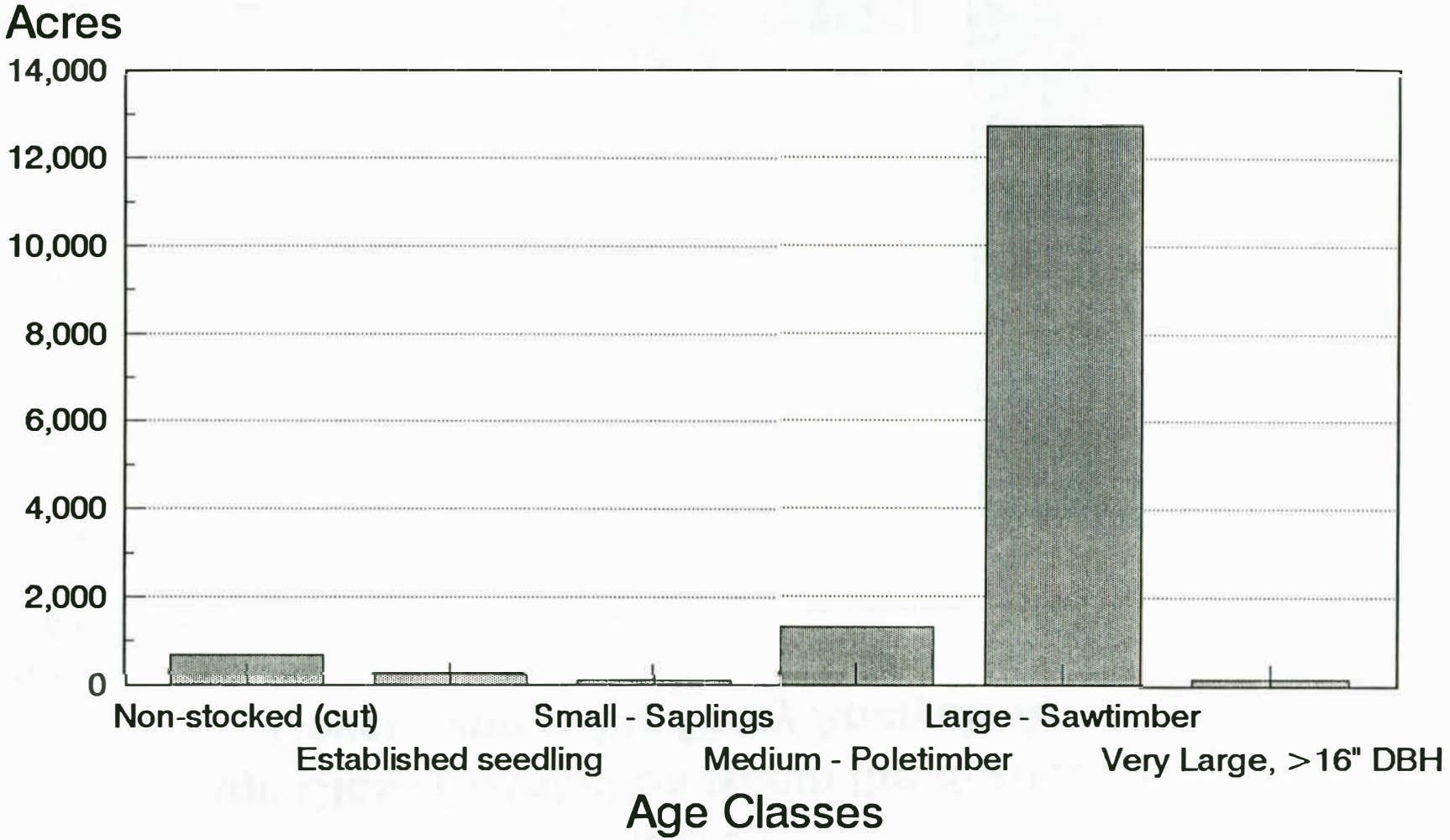


Figure 7
Age Class Distribution within the Spruce - Fir Cover Type of the Piney Analysis Area

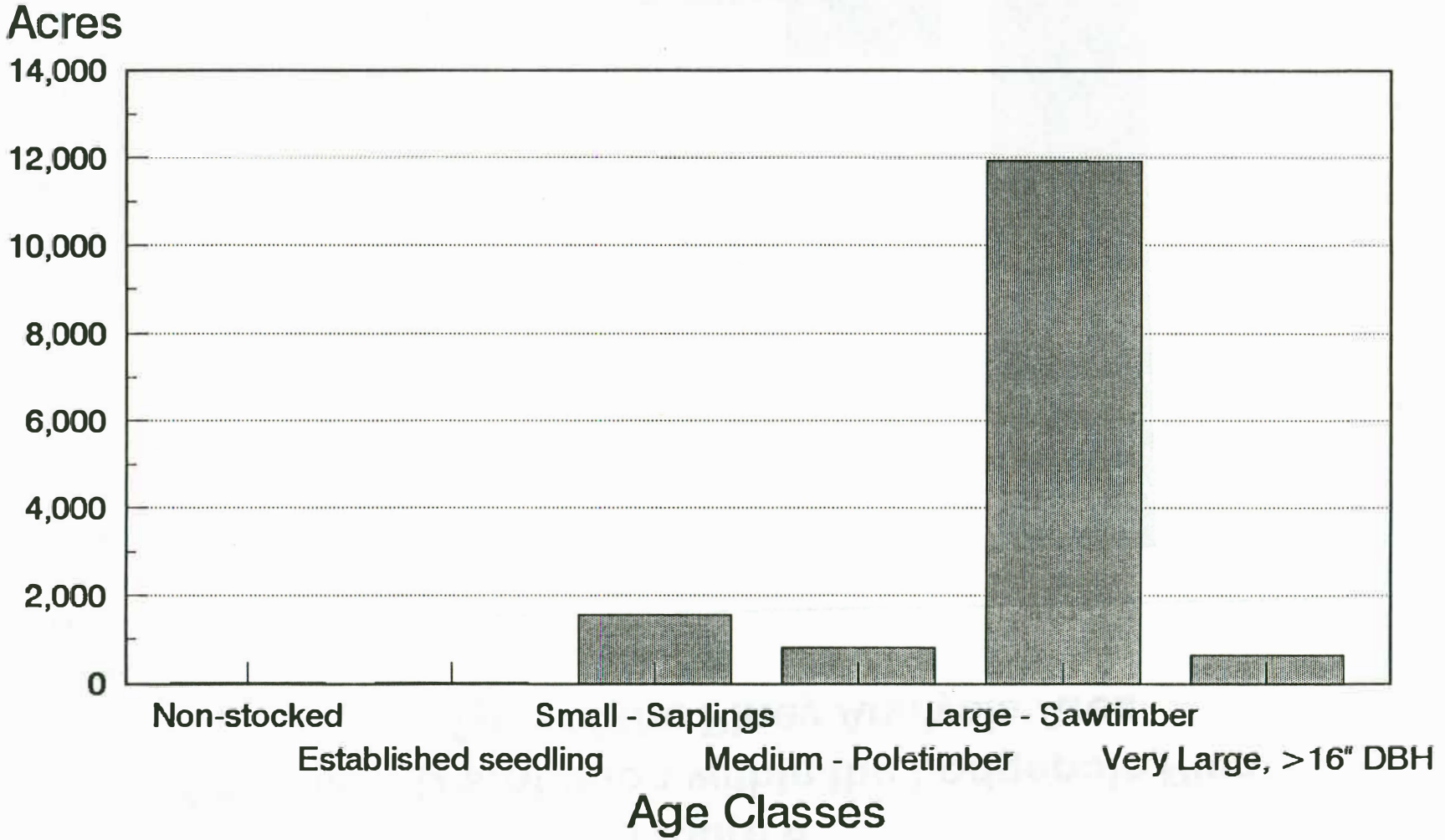


Figure 8
Age Class Distribution within the Douglas-fir Cover Type of the Piney Analysis Area

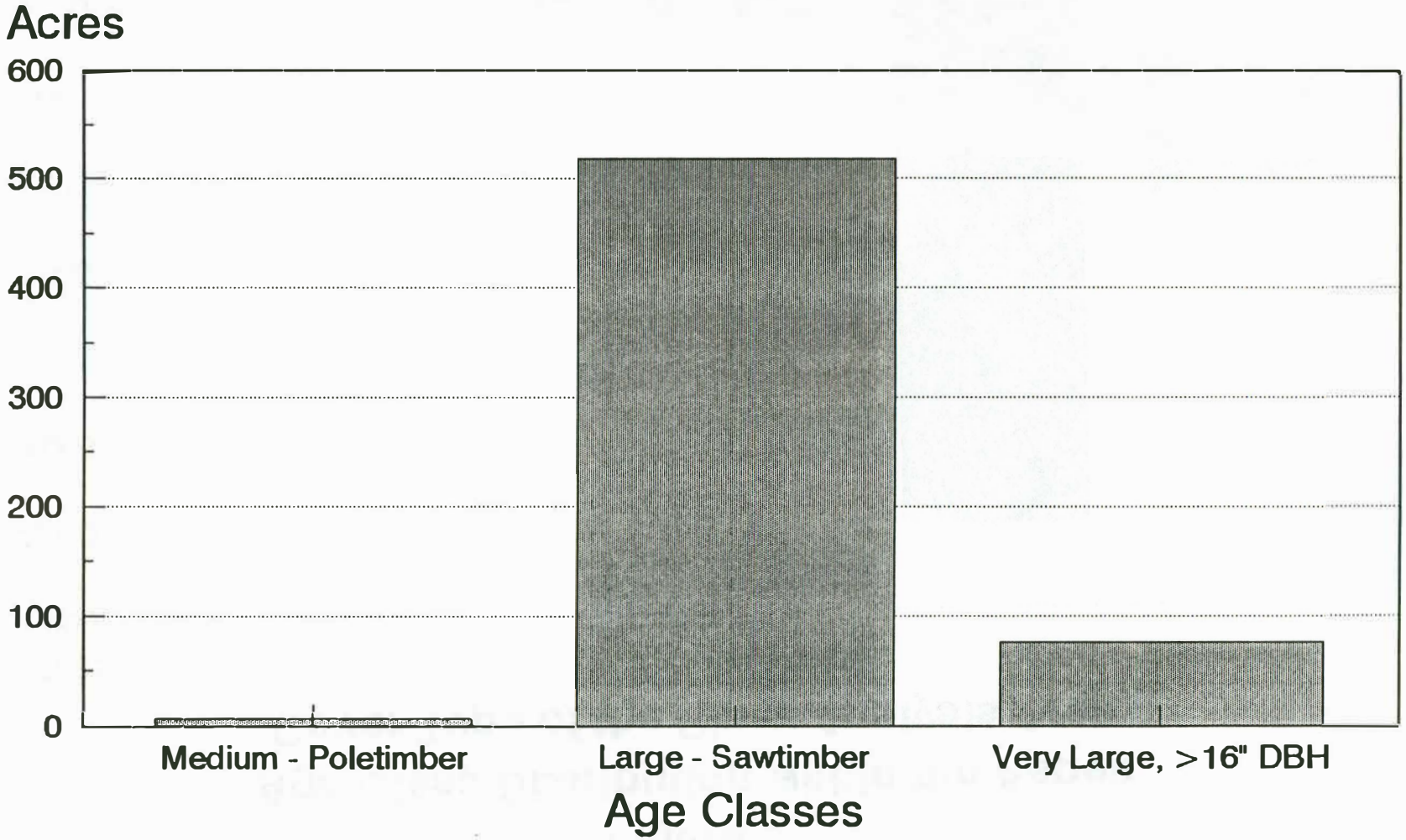
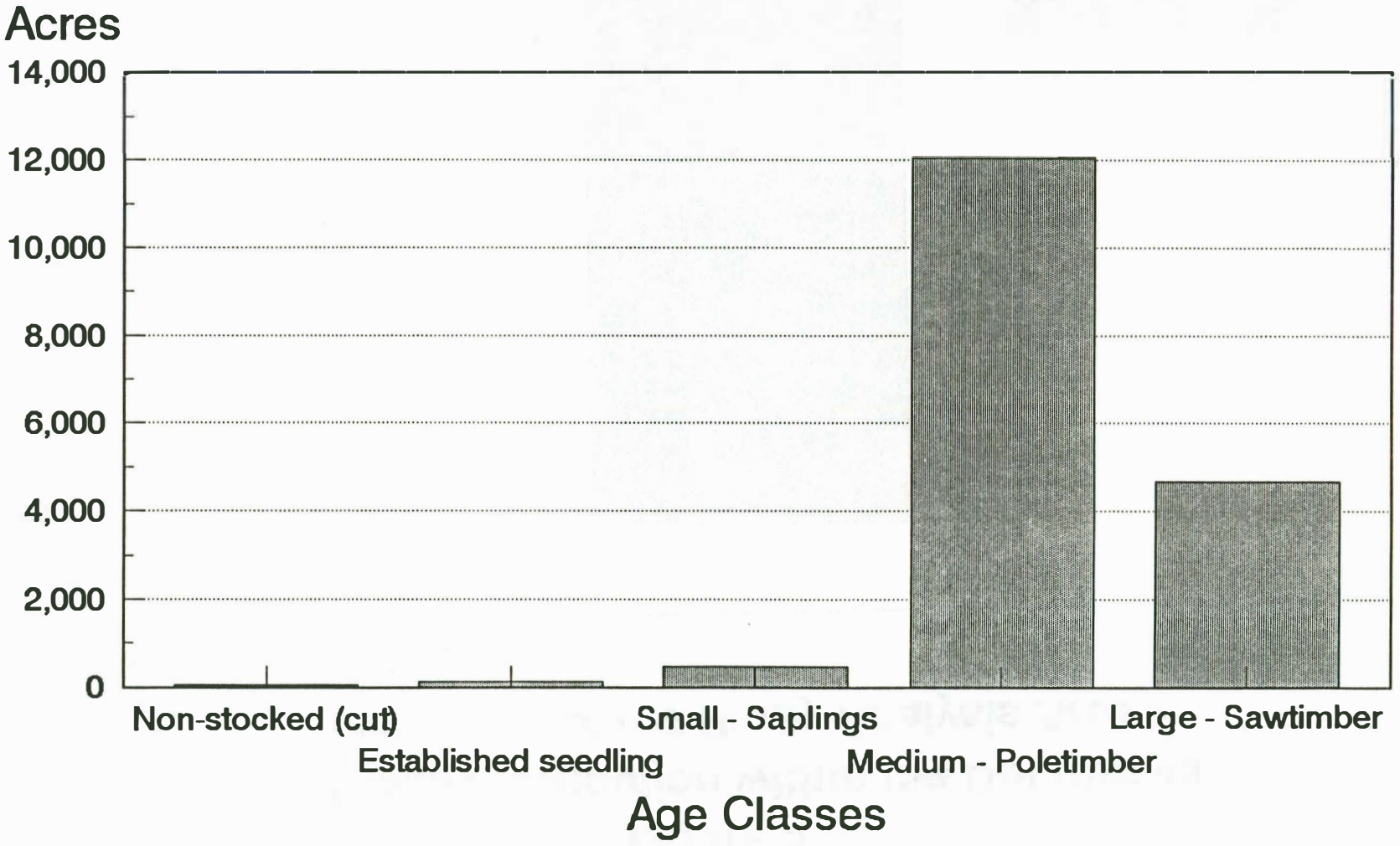


Figure 9
Age Class Distribution within the Aspen Cover Type of the Piney Analysis Area



Insect and Disease Conditions As Determined By All Available Data

Lodgepole Pine Cover Type

Standard Stage 2 stand exam data exists for most of the Forest Service lodgepole pine lands in the Piney Analysis Area. These stands were surveyed over a number of years, covering a period from 1976 until 1994 (the 1994 data is from the systematic stand exam described in Sections D-E). The stand susceptibility rating model of Amman et al. (1977) was applied to the data and stands were rated on their susceptibility to mountain pine beetle. Dwarf mistletoe information was also collected, and is presented in the form of dwarf mistletoe incidence (DMI) ratings. Because root disease data was only collected in 1994, these data are not addressed here. The mountain pine beetle and dwarf mistletoe data from the stand examinations are summarized in Table 4.

The mountain pine beetle susceptibility ratings indicate that 13% of the acreage in lodgepole pine stands are rated as having high susceptibility to mountain pine beetle, 79% had moderate risk, while the remaining 8% of the acres had low risk. Of the three factors which make up the susceptibility rating (average d.b.h., stand age and altitude/latitude), elevation was most responsible for differentiating high and moderate-risk stands. While nearly all stands received high susceptibility factor scores for average d.b.h. and age (which are interrelated), moderate risk stands were fairly high in elevation (a low-moderate susceptibility factor). The remaining low risk stands consist mostly of acres where clearcutting has occurred. This cutting occurred primarily in stands that previously had moderate or high risk levels.

The dwarf mistletoe data showed that 7% of the acres had high DMI levels (DMI = 4.0-6.0), 8% had moderate levels (DMI = 2.0-3.99), 6% had low levels (DMI = 0.1-1.99), and 79% had no dwarf mistletoe (DMI = 0).

Spruce/Subalpine Fir Cover Type

11,734 acres of Engelmann spruce/subalpine fir stands had stand exam data and were rated for spruce beetle risk (Schmid and Frye, 1976) by the RMSTAND program. Again, root disease data were not available. Ratings of stands that were located in well-drained creek bottoms were calculated by hand since the program cannot compute risk for those stands. Table 5 displays the data.

Of the stands surveyed for risk to spruce beetle, fully 80% of the acreage was at medium to high risk to spruce beetle loss.

Insect and Disease Conditions As Determined By The 1994 Survey

As stated previously, 77 of the 79 stands that were surveyed in 1994 (455 points) were included in the insect and disease analysis of the Piney Area. Attributes of these stands are

Table 4. Mountain pine beetle and dwarf mistletoe conditions for the lodgepole pine cover type of the Piney Analysis Area: all available data.

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1. Mountain Pine Beetle Risk

Total Analysis Area- 15184 acres (31% of total forested acres)

MPB Risk Rating:	Low:	1145 acres (8%)
	Moderate:	12045 acres (79%)
	High:	1994 acres (13%)

East Geographic Area- 8991 acres (59% of the lodgepole pine cover type)

MPB Risk Rating:	Low:	920 acres (10%)
	Moderate:	7231 acres (81%)
	High:	840 acres (9%)

South Geographic Area- 3374 acres (22% of the lodgepole pine cover type)

MPB Risk Rating:	Low:	32 acres (1%)
	Moderate:	3270 acres (97%)
	High:	72 acres (2%)

North Geographic Area- 2819 acres (19% of the lodgepole pine cover type)

MPB Risk Rating:	Low:	193 acres (7%)
	Moderate:	1544 acres (55%)
	High:	1082 acres (38%)

Table 4 (cont.). Mountain pine beetle and dwarf mistletoe conditions for the lodgepole pine cover type of the Piney Analysis Area: all available data.

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2. Dwarf Mistletoe Conditions

Total Analysis Area- 12829 acres (2355 acres were not rated for DMI)

DMI:	Low	(DMI = 0.1-1.99):	766 acres (6%)
	Moderate	(DMI = 2.0-3.99):	994 acres (8%)
	High	(DMI = 4.0-6.0):	900 acres (7%)
	Total	**(all infested areas):**	**2660 acres (21%)**

East Geographic Area- 7707 acres (60% of rated LPP cover type- 1284 acres were not rated for DMI)

DMI:	Low	(DMI = 0.1-1.99):	238 acres (3%)
	Moderate	(DMI = 2.0-3.99):	512 acres (7%)
	High	(DMI = 4.0-6.0):	900 acres (12%)
	Total:	**(all infected areas):**	**1650 acres (21%)**

South Geographic Area- 2871 acres (22% of rated LPP cover type- 503 acres were not rated for DMI)

DMI:	Low	(DMI = 0.1-1.99):	528 acres (18%)
	Moderate:	(DMI = 2.0-3.99):	289 acres (10%)
	High	(DMI = 4.0-6.0):	0 acres (0%)
	Total:	**(all infested areas):**	**817 acres (28%)**

North Geographic Area- 2251 acres (18% of rated LPP cover type- 568 acres were not rated for DMI)

DMI:	Low	(DMI = 0.1-1.99):	0 acres (0%)
	Moderate	(DMI = 2.0-3.99):	193 acres (9%)
	High	(DMI = 4.0-6.0):	0 acres (0%)
	Total	**(all infested areas):**	**193 acres (9%)**

Table 5. Spruce beetle risk analysis for the spruce/fir cover type of the Piney Analysis Area: all available data.

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1. Acres of S/F surveyed by size class.

V - Very Large	499 acres
L - Large	9,617 acres
M - Medium	365 acres
S - Saplings	1,253 acres
E - Est. Seedlings	0 acres
N - Nonstocked	0 acres
TOTAL:	11,734 acres

2. Spruce beetle risk rating of surveyed acres, by tree size.

SIZE	RISK RATING	ACRES	SIZE	RISK RATING	ACRES
V	5	0	M	5	0
	4	168		4	0
	3	331		3	78
	2	0		2	101
	1	0		1	186
L	5	430	S	5	0
	4	1,969		4	0
	3	6,081		3	347
	2	729		2	370
	1	408		1	536

3. Summary - Spruce beetle risk ratings.

5 = High	430 acres	(4%)
4 = Medium High	2,137 acres	(18%)
3 = Medium	6,837 acres	(58%)
2 = Medium Low	1,200 acres	(10%)
1 = Low	1,130 acres	(10%)

---

listed in Appendix B. 38 stands were in the eastern geographic area, 20 in the northern and 19 in the southern. All stands contained at least 10% basal area in lodgepole pine. Of the 78 stands in the survey, only 5 (6%) were on slopes greater than 40%.

Mountain Pine Beetle Conditions

Table 6 summarizes the mountain pine beetle risk levels that were identified in the 1994 survey. 83% of the surveyed area was found to be at moderate to high risk, and the greatest amount of high risk was in the northern geographic area. Again, elevation was most responsible for differentiating high and moderate-risk stands. All 5 stands that were on slopes greater than 40% received high risk ratings.

Dwarf Mistletoe Conditions

Table 7 summarizes lodgepole pine dwarf mistletoe incidence and severity, as determined by the 1994 survey. While dwarf mistletoe is widespread throughout the analysis area (17% of the total surveyed acres), the greatest levels were found in the east geographic area (20%), and the least in the north (11%). The 17% figure for total acreage affected by dwarf mistletoe, however, is significantly lower than the 36% figure that was found in 1979 for the entire forest (Johnson et al., 1980).

Stands with DMR ratings of 2 or greater generally cannot be sanitized by thinning and must undergo sanitation patch-cutting or clearcutting. However, because DMR ratings include ratings of all trees in a stand and DMI ratings only include infected trees, DMR ratings are generally lower than DMI ratings. Because of this, the combined percentages of acres in the moderate and high DMI classes should be considered as a maximum figure of the acres whose dwarf mistletoe problems cannot be adequately addressed by sanitation thinning alone.

Root Disease Conditions

The root disease conditions of the Piney Analysis Area, as revealed by the 1994 survey, are summarized in Table 8. Overall, Armillaria root disease is widespread throughout the analysis area. The root disease fungus was identified on over half (53%) of the acres surveyed. Disease incidence was greatest in the northern geographic area (83%) and lowest in the east (38%), but the greatest amount of high infestation levels (root disease identified in >41% of sample points) was in the eastern geographic area (20% high incidence).

Management activities to address root disease may be considered in the moderate to high infected acres. However, in the Rocky Mountains, and in the absence of other stressing agents, Armillaria root disease mainly tends to affect lodgepole pines that are less than 25 years old (Sharon, 1988). As the pines become older, mortality decreases, though growth reduction may still be significant. However, exceptions to this scenario, where mortality occurs throughout all age and size classes, do occur. Because of this, stands that contain

Table 6. Mountain pine beetle risk analysis for the lodgepole pine cover type of the Piney Analysis Area: 1994 survey.

Total Analysis Area (3218 acres, 77 stands, 455 points rated for MPB)					
MPB Risk Rating:	Low:	131 acres	(4%),	3 stands	(4%)
	Moderate:	2282 acres	(71%),	54 stands	(70%)
	High:	805 acres	(25%),	20 stands	(26%)
East Geographic Area(1678 acres, 38 stands, 230 points rated for MPB)					
MPB Risk Rating:	Low:	73 acres	(4%),	1 stands	(3%)
	Moderate:	1453 acres	(86%),	29 stands	(76%)
	High:	152 acres	(9%),	8 stands	(21%)
South Geographic Area(735 acres, 19 stands, 103 points rated for MPB)					
MPB Risk Rating:	Low:	58 acres	(8%),	2 stands	(11%)
	Moderate:	620 acres	(84%),	16 stands	(84%)
	High:	57 acres	(8%),	1 stand	(5%)
North Geographic Area(805 acres, 20 stands, 122 points rated for MPB)					
MPB Risk Rating:	Low:	0 acres	(0%),	0 stands	(0%)
	Moderate:	209 acres	(26%),	9 stands	(45%)
	High:	596 acres	(74%),	11 stands	(55%)

Table 7. Dwarf mistletoe conditions for the lodgepole pine cover type of the Piney Analysis Area: 1994 survey.

Total Analysis Area (3218 acres, 77 stands, 455 points)						
DMI:	Low	(DMI = 0.1-1.99):	149 acres	(5%),	5 stands	(6%)
	Moderate	(DMI = 2.0-3.99):	290 acres	(9%),	10 stands	(13%)
	High	(DMI = 4.0-6.0):	121 acres	(4%),	2 stands	(3%)
	TOTAL	**(all infested areas):**	**560 acres**	**(17%),**	**17 stands**	**(22%)**
East Geographic Area(1678 acres, 38 stands, 230 points)						
DMI:	Low	(DMI = 0.1-1.99):	77 acres	(5%),	3 stands	(8%)
	Moderate:	(DMI = 2.0-3.99):	142 acres	(8%),	7 stands	(18%)
	High	(DMI = 4.0-6.0):	121 acres	(7%),	2 stands	(5%)
	TOTAL:	**(all infested areas):**	**340 acres**	**(20%),**	**12 stands**	**(31%)**
South Geographic Area(735 acres, 19 stands, 103 points)						
DMI:	Low	(DMI = 0.1-1.99):	72 acres	(10%),	2 stands	(11%)
	Moderate:	(DMI = 2.0-3.99):	60 acres	(8%),	2 stands	(11%)
	High	(DMI = 4.0-6.0):	0 acres	(0%),	0 stands	(0%)
	TOTAL:	**(all infested areas):**	**132 acres**	**(18%),**	**4 stands**	**(21%)**
North Geographic Area(805 acres, 20 stands, 122 points)						
DMI:	Low	(DMI = 0.1-1.99):	0 acres	(0%),	0 stands	(0%)
	Moderate	(DMI = 2.0-3.99):	88 acres	(11%),	1 stand	(5%)
	High	(DMI = 4.0-6.0):	0 acres	(0%),	0 stands	(0%)
	TOTAL	**(all infested areas):**	**88 acres**	**(11%),**	**1 stand**	**(5%)**

Table 8. Root disease conditions for the lodgepole pine cover type of the Piney Analysis Area: 1994 survey.

Total Analysis Area (3218 acres, 77 stands, 455 points)						
RD:	Low	(RD = 1-20%):	1092 acres	(34%)	19 stands	(25%)
	Moderate	(RD = 21-40%):	186 acres	(6%),	6 stands	(8%)
	High	(RD > 41%):	434 acres	(13%)	14 stands	(18%)
	TOTAL	**(all infested areas):**	**1712 acres**	**(53%),**	**39 stands**	**(51%)**
East Geographic Area(1678 acres, 38 stands, 230 points)						
RD:	Low	(RD = 1-20%):	264 acres	(16%)	7 stands	(18%)
	Moderate	(RD = 21-40%):	31 acres	(2%),	2 stands	(5%)
	High	(RD > 41%):	336 acres	(20%)	9 stands	(24%)
	TOTAL	**(all infested areas):**	**631 acres**	**(38%),**	**18 stands**	**(47%)**
South Geographic Area(735 acres, 19 stands, 103 points)						
RD:	Low	(RD = 1-20%):	220 acres	(30%)	4 stands	(22%)
	Moderate	(RD = 21-40%):	154 acres	(21%)	3 stands	(17%)
	High	(RD > 41%):	38 acres	(5%)	2 stands	(11%)
	TOTAL	**(all infested areas):**	**412 acres**	**(56%),**	**9 stands**	**(47%)**
North Geographic Area(805 acres, 20 stands, 122 points)						
RD:	Low	(RD = 1-20%):	608 acres	(76%)	8 stands	(40%)
	Moderate	(RD = 21-40%):	0 acres	(0%)	0 stands	(0%)
	High	(RD > 41%):	60 acres	(7%)	3 stands	(15%)
	TOTAL	**(all infested areas):**	**668 acres**	**(83%),**	**12 stands**	**(60%)**

the root disease should be monitored in order to identify the patterns of disease impact. If mortality occurs in larger pines, or if root disease patches fail to regenerate, then management activities beyond monitoring, such as patch clearcutting or the silvicultural favoring of more disease-tolerant species (such as aspen, ponderosa pine or spruce) may be considered.

Comparison of the "All Available Data" and "1994 Survey" Data Sets

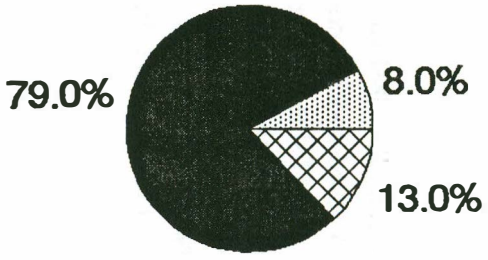
A comparison of the mountain pine beetle risk values obtained from the "all available data" and the "1994 survey" data sets is shown in Figure 10. The "all available data" set shows that 13 percent of the lodgepole pine acres were at high risk to mountain pine beetle attack and 70 percent were at moderate risk. In contrast, the 1994 survey indicated that 25 percent of the lodgepole pine acres were at high risk and 71 percent at moderate risk (Figure 10). The highest risk acres were located in the north geographic area; moderate risk acres were located in both the east and south areas.

The "all available data" set shows that 21 percent of the lodgepole pine acres were infested with dwarf mistletoe, whereas the 1994 survey estimated that 17 percent of the acres were infested. The greatest amount of the disease was in the eastern geographic area and the least in the north. Only 13 percent of the acres were rated as moderate to high and should be considered for management activities in the near future.

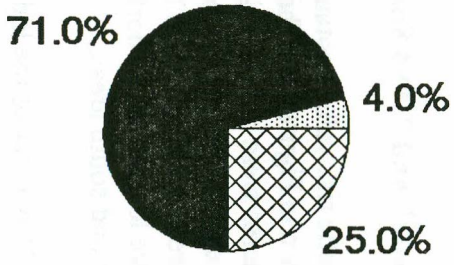
Since root disease information was not collected prior to 1994, we are not able to compare root disease incidence. The survey indicates 19 percent of the acres with moderate to high levels of root disease. *Armillaria spp.* was present in 52 percent of the acres sampled. The north geographic area had the greatest number of stands with root disease (83%); however, most (76%) was at low incidence. The most severe infestations were located in the east.

Although there are many similarities between the "1994 survey" and "all available data" sets, there are many differences as well. A stand-specific comparison of data that was collected both in 1994 and in a previous year (Table 9) further illustrates observed differences in DMI, Live Basal Area and Quadratic Mean Diameter. Overall, we have greater confidence in the "1994 survey" data set. This is because the 1994 data represents a statistical sample of the stands in the analysis area and the survey was modified to more accurately and completely collect insect and disease data. In addition, the data was collected over a single season, and the survey crews were specifically trained in how to most effectively look for, identify and quantify tree insects and diseases. Therefore, from this point on, the assessment will concentrate on the 1994 data.

Figure 10
Comparison of Pine Beetle Ratings between "All Available Data" and "1994 Survey" data sets



Risk Rating based on "All available data"



Risk Rating based on 1994 Survey

Low Moderate High

Piney Analysis Area - White River NF

Table 9. Stand-specific comparison of data collected both in 1994 and in a previous year.

LOCATI	SITE	OLD SURVEY DATE	DMI OLD	DMI 1994	LIVE BASAL AREA (ft^2/acre) OLD	LIVE BASAL AREA (ft^2/acre) 1994	QUADRATIC MEAN DIAMETER (in.) OLD	QUADRATIC MEAN DIAMETER (in.) 1994
101005	0006	1976	0	0	135	80	8.2	8.8
101005	0009	1990	M	0	173	224	10.3	10.2
101101	0036	1983	L	0	133	166	10.0	9.8
101101	0037	1983	M	0	80	115	9.0	9.8
101103	0013	1986	0	M	164	173	8.0	9.8
101104	0015	1986	L	0	132	168	10.0	11.1
101320	0010	1986	0	M	160	160	8.0	9.0
107001	0007	1990	0	0	160	176	11.4	8.5
107001	0030	1982	0	0	140	108	9.0	10.7
107001	0033	1982	0	0	133	88	7.0	11.6
107002	0018	1982	0	0	154	133	10.0	9.5
107002	0020	1982	0	0	145	200	10.0	11.0
107003	0017	1982	H	M	170	160	7.0	7.9
107004	0007	1982	M	H	116	117	11.0	11.7
107004	0009	1982	0	0	180	144	9.0	9.2
107004	0010	1982	M	M	170	140	7.0	8.1
107004	0015	1982	H	0	129	165	9.0	9.4
107004	0019	1982	M	0	144	172	8.0	9.7
107005	0003	1982	0	M	120	192	10.0	10.0
107005	0007	1982	H	H	95	167	9.0	9.6
107101	0042	1982	0	0	184	208	10.0	10.2
107102	0027	1982	0	0	210	200	10.0	11.1
107202	0006	1985	0	0	114	72	12.0	14.2
107301	0009	1986	0	0	108	50	12.0	18.1
107303	0004	1976	P	0	205	209	9.0	9.6
107303	0017	1976	P	0	205	310	9.0	8.5
107303	0018	1976	P	L	205	168	9.0	10.3
107303	0019	1976	P	0	205	200	9.0	9.2
107304	0001	1976	0	0	163	208	9.0	10.6

H = High (DMI = 4.0 - 6.0)
M = Moderate (DMI = 2.0 - 3.99)
L = Low (DMI = 0.1 - 1.99)
0 = No dwarf mistletoe
P = Dwarf mistletoe noted in Stand Exam, but not rated

Insect/Disease Interactions- 1994 Survey

Analysis of areas with various combinations of mountain pine beetle risk (MPB), dwarf mistletoe (DM) and root disease (RD) are presented in Table 10. Assuming that the sample is representative of the area as a whole, 13 percent of the area is rated as moderate to high susceptibility to MPB x DM (area within the matrix that is enclosed by the box in the lower right corner); 20 percent as moderate to high for MPB x RD; and 2 percent as moderate to high for DM x RD.

Mountain Pine Beetle x Dwarf Mistletoe

As shown in Table 10-1, approximately 18% of the acres have mountain pine beetle management concerns (Moderate to High susceptibility levels and also contain some dwarf mistletoe (Low, Moderate or High levels). Thirteen percent of the acres rated moderate to high for both mountain pine beetle and dwarf mistletoe incidence. In these acres, thinning alone may not adequately address both dwarf mistletoe and mountain pine beetle problems. As stated previously, because the stands with a DMR rating of 2 or greater (the limit of applicability of sanitation thinning) is a subset of the stands with a DMI rating of 2 or greater, the 13% figure for stands whose dwarf mistletoe/mountain pine beetle problems cannot be adequately addressed by sanitation thinning alone must be considered as a maximum figure. Silvicultural treatments are best determined on a stand-by stand, landscape-by-landscape basis. Where thinning may be applied to address a dwarf mistletoe situation (stand DMR < 2.0), sanitation thinning for dwarf mistletoe and thinning to reduce bark beetle risk should be combined into a single integrated treatment.

Mountain Pine Beetle x Root Disease

According to Table 10-2, 54% of the surveyed analysis area has some (high, medium or low) level of root disease and moderate to high bark beetle risk, but only 20% has both moderate to high bark beetle risk and moderate to high levels of root disease. As stated before, special treatments to address root disease (such as patch cutting or replacement with more tolerant species) will likely not be necessary in most areas. However, because root disease infection centers may also serve as focus points for the initiation of bark beetle epidemics, stands with moderate to high levels of root disease and bark beetle risk should be targeted first for thinning treatments aimed at reducing bark beetle susceptibility. These stands will need to be closely monitored, because thinning can result in increased levels of buried root disease inoculum in the remaining stumps. If increased root disease mortality is noted in the remaining pines, followup treatments may be necessary to address the root disease situation.

Dwarf Mistletoe x Root Disease

As seen in Table 10-3, 10% of the surveyed acres contain both dwarf mistletoe and Armillaria root disease, but in only 2% are both disease levels moderate or high. Since root disease is seldom a major management problem in lodgepole pine, in most cases,

Table 10. Interactions between mountain pine beetle risk, dwarf mistletoe, and root disease incidence at the Piney Analysis Area: 1994 survey.

1. Dwarf Mistletoe Infection x Mountain Pine Beetle Susceptibility

	Susceptibility to Mountain Pine Beetle		
Dwarf Mistletoe Infection	**Low**	**Moderate**	**High**
None (DMI = 0)	105 (3%)	1,779 (55%)	774 (24%)
Low (DMI = 0.1-1.99)	0 (0%)	126 (4%)	23 (1%)
Moderate (DMI = 2.0-3.99)	0 (0%)	256 (8%)	34 (1%)
High (DMI = 4.0-6.0)	0 (0%)	121 (4%)	0 (0%)

2. Root Disease Rating x Mountain Pine Beetle Susceptibility

	Susceptibility to Mountain Pine Beetle		
Stand Root Disease Rating	**Low**	**Moderate**	**High**
None (0% infected)	105 (3%)	1,173 (36%)	228 (7%)
Low (1-20% infected)	0 (0%)	585 (18%)	507 (16%)
Moderate (21-40% infected)	0 (0%)	186 (6%)	0 (0%)
High (> 41% infected)	0 (0%)	335 (11%)	96 (3%)

Table 10 (cont.). Interactions between mountain pine beetle risk, dwarf mistletoe, and root disease incidence at the Piney Analysis Area: 1994 survey.

3. Dwarf Mistletoe Infection x Root Disease Rating

Dwarf Mistletoe Infection	Stand Root Disease Rating: None 0%	Low 1-20%	Moderate 21-40%	High > 71%
None (DMI = 0)	1285 (40%)	829 (26%)	145 (5%)	399 (12%)
Low (DMI = 0.1-1.99)	115 (4%)	34 (1%)	0 (0%)	0 (0%)
Moderate (DMI = 2.0-3.99)	106 (3%)	108 (3%)	41 (1%)	35 (1%)
High (DMI = 4.0-6.0)	0 (0%)	121 (4%)	0 (0%)	0 (0%)

management for dwarf mistletoe will be the driving force for management decisions in these stands. The decision to apply sanitation thinning or patch cutting will depend on the amount and distribution of the dwarf mistletoe (no thinning if stand DMR> 2.0). Again, the particular treatment to be applied must be determined on a stand-by-stand, landscape-by-landscape basis. As with the stands with both bark beetle risk and root disease, any stands that are thinned (in this case, for dwarf mistletoe), will need to be closely monitored for increased root disease activity.

G. Forest Pest Model Runs and Interpretation

Sampling Stands For Pest Model Runs

In order to gain a better understanding of the potential impacts of mountain pine beetle, lodgepole pine dwarf mistletoe, and Armillaria root disease on the lodgepole pine stands of the Piney Analysis Area, a sample of stands were chosen as example stands to simulate the effects of the various insects and diseases over 10 cycles (100 years). Stand growth was simulated utilizing the Forest Vegetation Simulator (FVS) Version 6.2, Central Rockies Lodgepole Pine Variant. To simulate mountain pine beetle and Armillaria root disease effects, the Mountain Pine Beetle and Western Root Disease pest extension models were used. To simulate dwarf mistletoe effects, the base FVS model was run with and without dwarf mistletoe effects (MISTOFF engaged and not engaged). Nineteen stands from the 1994 survey were chosen as example stands for model runs. To insure that a wide variety of initial insect and disease intensities were represented, the stands were chosen from the various strata identified from the DM x MPB and DM x Root Disease interaction grids (Table 10-1 and 10-2).

Mountain Pine Beetle

In order to get a better picture of what the impact of mountain pine beetle might be within the Piney Analysis Area in the years to come, data collected during the 1994 survey was used in a number of runs of the FVS model. The design of this simulation model allows the user to manipulate stand conditions and thus gain some insight into the types of impact the various components of the ecosystem are having on the final condition of the stand. The results of these computer simulations are not meant to be "predictions" of future conditions, but instead allow a user to compare the impact of the various parameters.

The stands were divided into 3 groups (Low, Moderate and High) according to mountain pine beetle susceptibility ratings. At least one stand was randomly chosen from each group for a total of 6 stands. Each of the chosen stands was run through the model several times under various assumptions. Table 11-1 lists the stands selected to be run in the model as well as some key characteristics. Table 11-2 gives the results of the runs

Table 11. Results of Forest Vegetation Simulator/Mountain Pine Beetle Model runs.

1. Stands Run Through FVS-MPB Model Simulations

Stand ID	Stand age	LPP (%TPA)	MPB susceptibility rating
107202-6	81	91	Low
101315-22	72	95	Mod
101005-9	100	62	Mod
107003-17	89	61	Mod
107004-7	75	93	Mod
107001-11	85	62	High

2. Volume Loss in 10 Cycles, MPB Outbreak Starting In Year 1994

Stand ID	Cubic volume without outbreak	Cubic volume with outbreak	Reduction in volume (%)
107202-6	4635	2377	49
101315-22	11595	3953	66
101005-9	13162	7882	40
107003-17	7048	6221	12
107004-7	6739	5362	20
107001-11	7700	5720	26

under the assumption that there is no mountain pine beetle outbreak vs. an outbreak starting in 1995. The volume is expressed in total cubic feet.

The FVS model simulates an outbreak of mountain pine beetle by taking stand factors into account and keeping track of mortality during the cycle of the simulated outbreak. Figure 11 is an example of the way that tree mortality may occur in a stand. Once the stand has been subjected to the outbreak, the decreased volume renders the stand less susceptible to additional outbreaks in the near term.

These results indicate a loss in volume that ranges from 12 to 66% over the 100 year length of the simulation. The expression of these losses does not simply represent just a loss of timber, these volume changes also represent increased fuel loading, changes in value to wildlife, recreational amenities, etc. Volume losses as great as 66% really represent the dramatic changes in stand structure and dynamics which mountain pine beetle are capable of.

Additional runs were made to determine what the impact of mountain pine beetle outbreaks occurring at various points during the 100 year period would be. Runs were made of one randomly chosen stand from each of the beetle susceptibility classes. Figures 12-14 present the results of these runs. These stands were run under a series of different assumptions which were 1) No pest impact of any kind, 2) Impact of Dwarf mistletoe only, 3) Outbreak in 1994, 4) Outbreak in 2004, 5) Outbreak in 2024.

Just as these stands differed greatly, so did the results of the runs. One surprising result of these runs was that the timing of the outbreak usually did not make a great difference in the total volume at the end of the 100 year period. The generally slow recovery from an outbreak illustrates the long term impact of a mountain pine beetle outbreak.

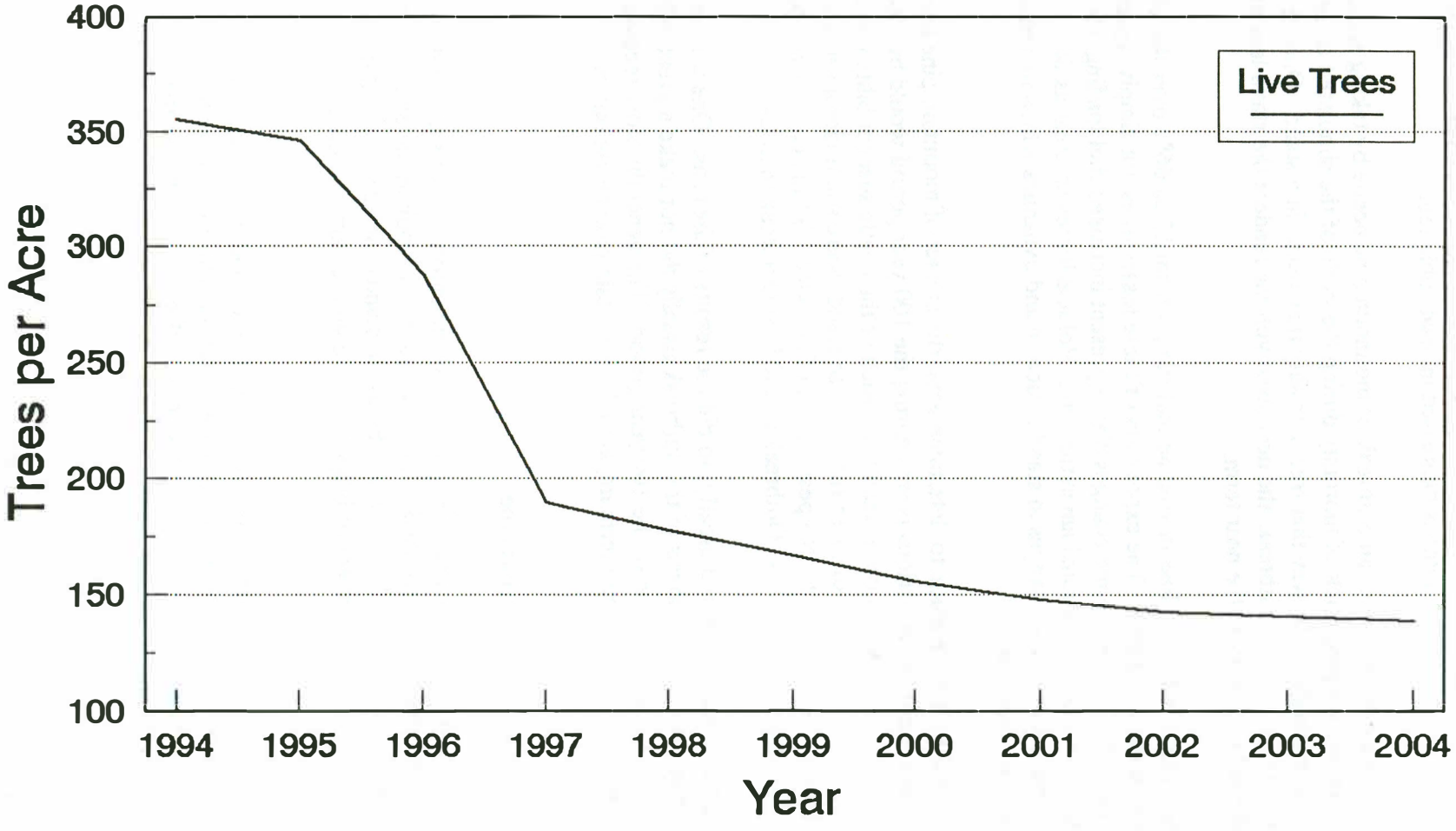
Lodgepole Pine Dwarf Mistletoe

Nine stands, representing a sample of the stands inventoried with varying degrees of dwarf mistletoe infection, were selected as example stands to simulate the effects of dwarf mistletoe over 10 cycles (100 years). The list of stands analyzed, with stand age, percent of lodgepole pine, and percent of lodgepole pine with dwarf mistletoe is presented in Table 12-1.

Each stand was run with the current dwarf mistletoe condition to determine growth and mortality effects of the disease and again without the dwarf mistletoe function. The difference between the two simulations gave the effect of the disease over the simulation period. A summary of the results of the stand simulations is presented in Table 12-2.

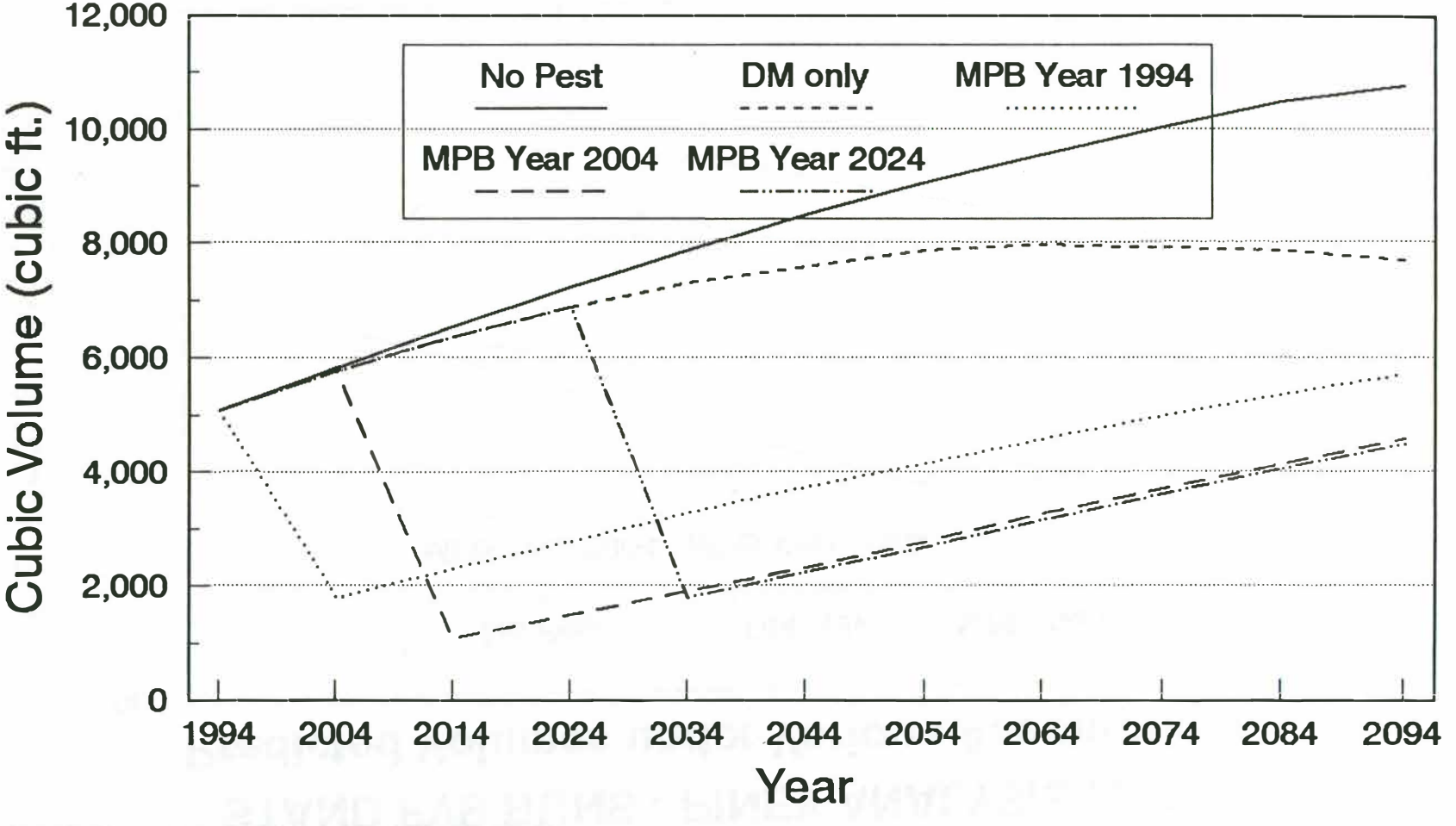
The impact of dwarf mistletoe on cubic volume over the 10-cycle period for three of the stands (high, medium and low DM levels) is shown in Figures 15-17. The reduction in total cubic foot volume of stands infested with dwarf mistletoe ranged from 11.2 to 53.3

Figure 11
STAND FVS RUN - PINEY ANALYSIS AREA
Simulation of Pine Beetle Outbreak



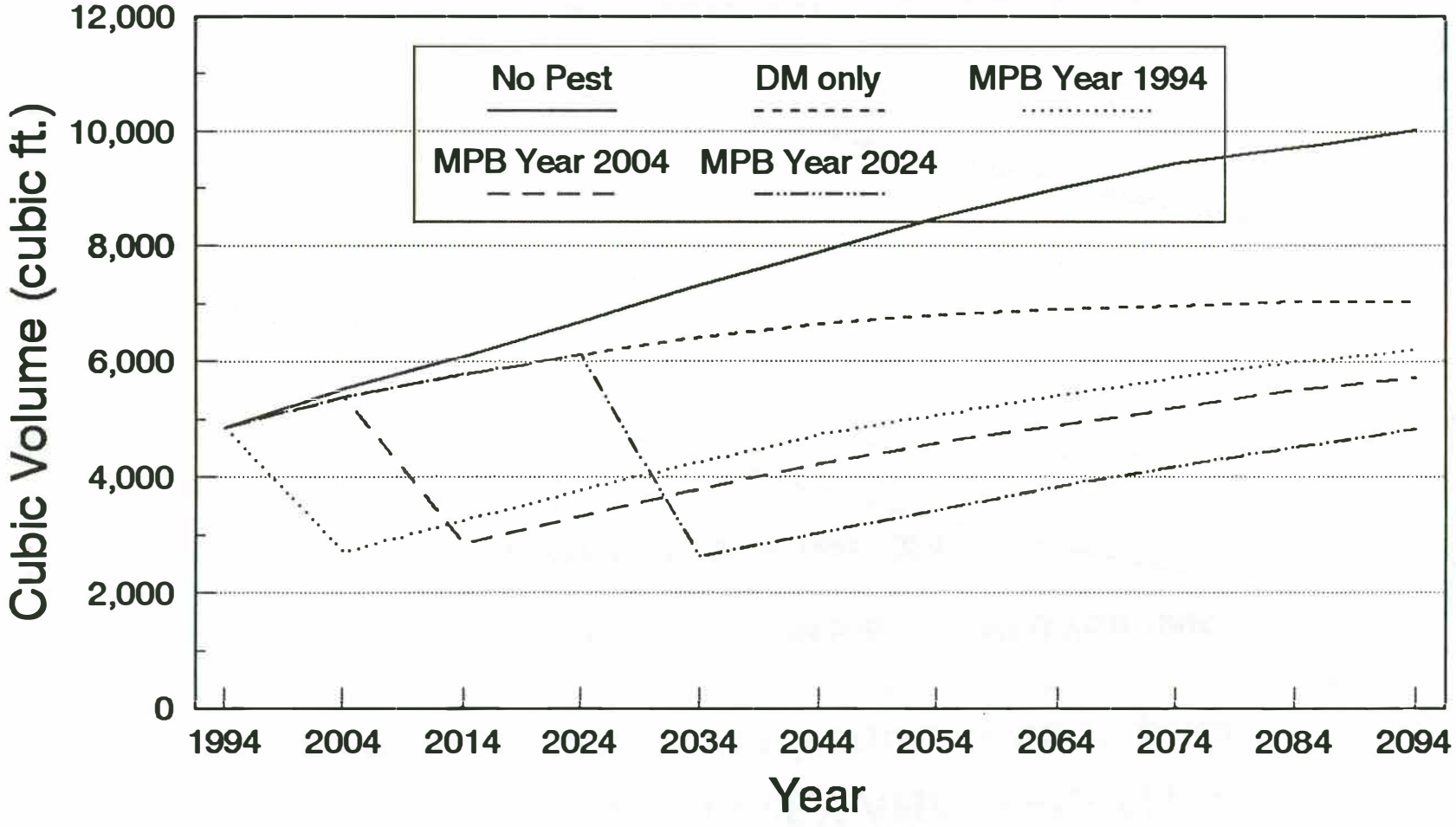
Stand 101005-9

Figure 12
STAND FVS RUNS - PINEY ANALYSIS AREA
Predicted Volumes under Various Assumptions



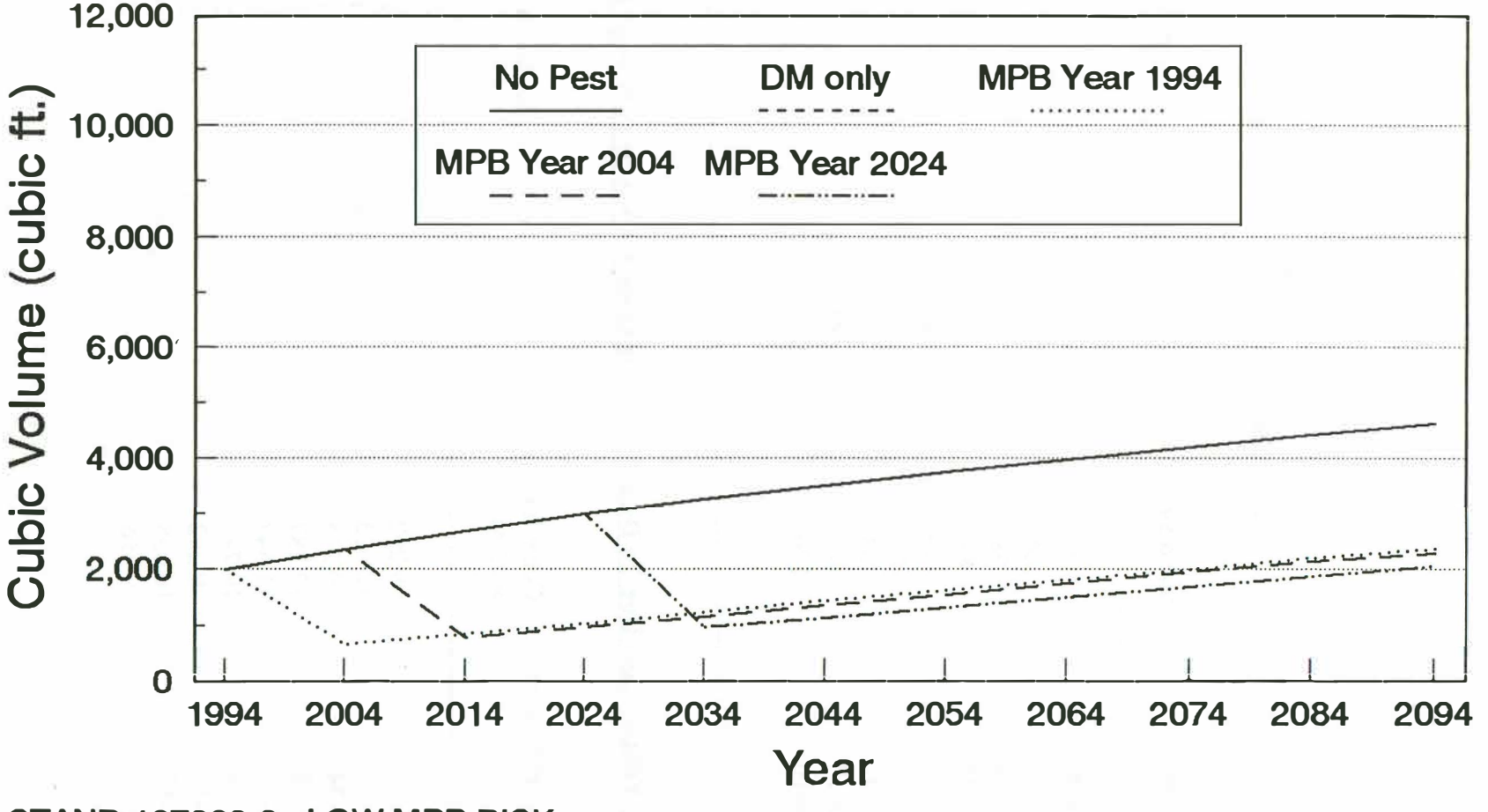
STAND 107001-11 - HIGH MPB RISK

Figure 13
STAND FVS RUNS - PINEY ANALYSIS AREA
Predicted Volumes under Various Assumptions



STAND 107003-17 - MEDIUM MPB RISK

Figure 14
STAND FVS RUNS - PINEY ANALYSIS AREA
Predicted Volumes under Various Assumptions



STAND 107202-6 - LOW MPB RISK

Note: There was no DM in this stand

Table 12. Results of Forest Vegetation Simulator/Dwarf Mistletoe Model runs.

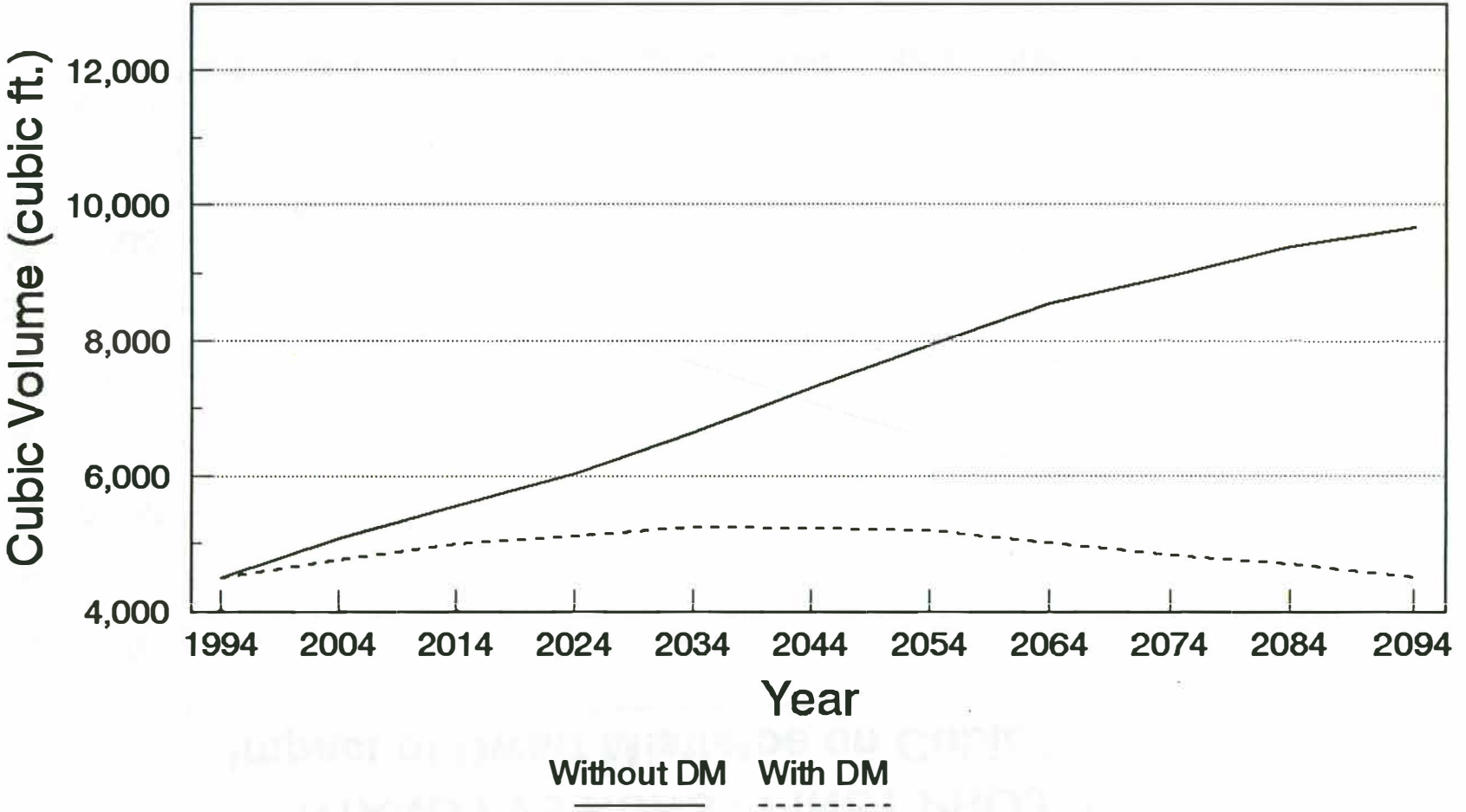
1. Stands Run Through FVS-DM Model Simulations

Stand identification	Stand age	LPP (%TPA)	LPP with DM (%)
107004-7	75	93	2.8
101103-13	84	79	6.8
100901-34	98	87	10.5
107303-18	84	89	15.0
107005-7	114	87	27.2
107001-11	85	62	28.6
107005-3	131	74	36.0
107003-17	89	61	66.6
107004-10	126	93	92.3

2. Volume Loss Due To Dwarf Mistletoe Over A 10-cycle (100 year) Period

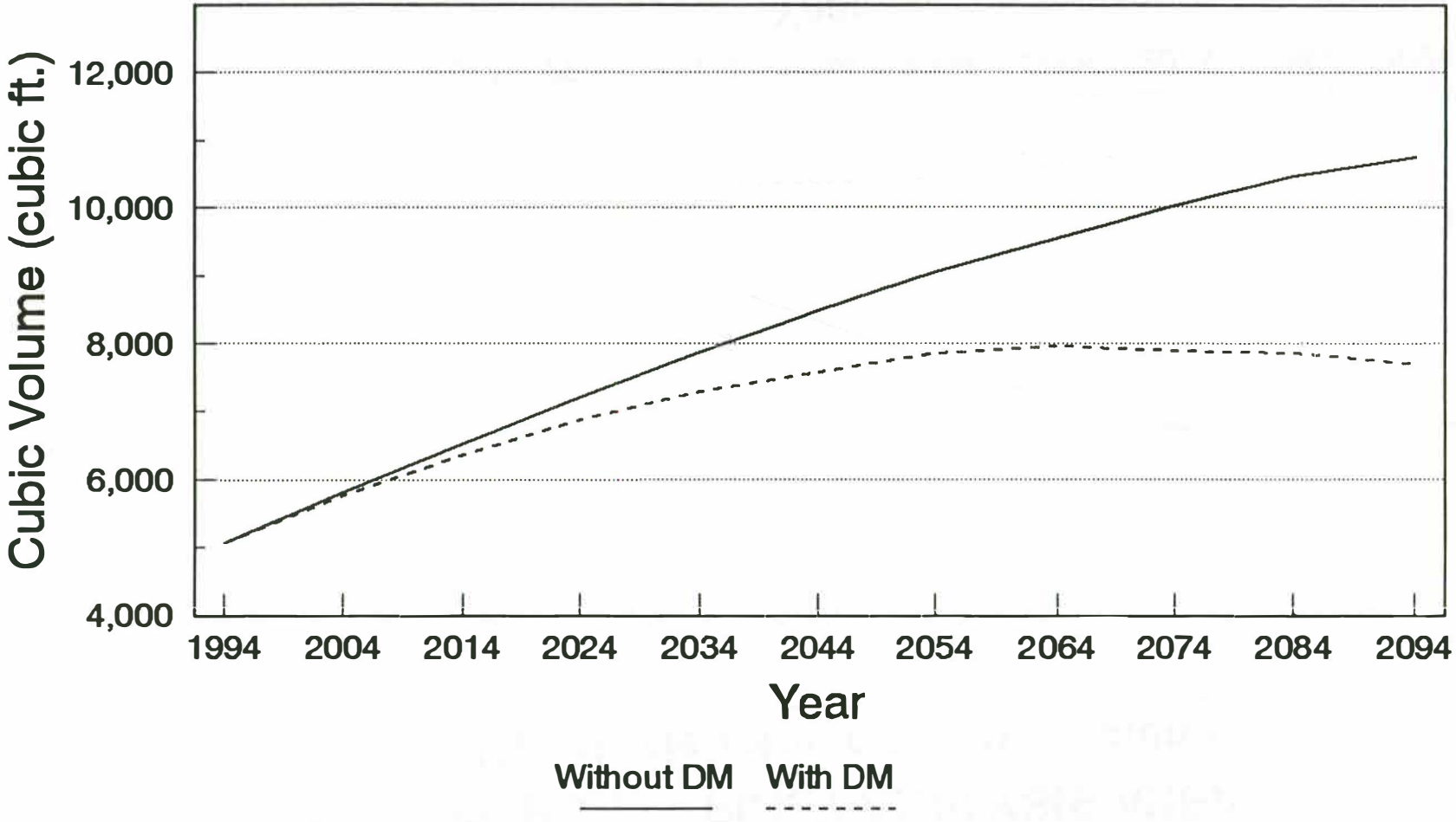
Stand identification	Cubic foot volume wo/DM	Cubic foot volume w/DM	Vol. diff. (cu. ft.)	Reduction in volume (%)
107004-7	9,292	6,739	-2,553	27.5
101103-13	12,023	10,678	-1,345	11.2
100901-34	9,245	7,491	-1,754	18.9
107303-18	12,287	10,411	-1,876	15.3
107005-7	11,647	9,640	-2,007	17.2
107001-11	10,749	7,700	-3,049	28.4
107005-3	9,232	7,178	-2,054	22.2
107003-17	10,038	7,048	-2,990	29.8
107004-10	9,666	4,509	-5,157	53.3

Figure 15
STAND FVS RUNS - PINEY ANALYSIS AREA
Impact of Dwarf Mistletoe on Cubic Volume



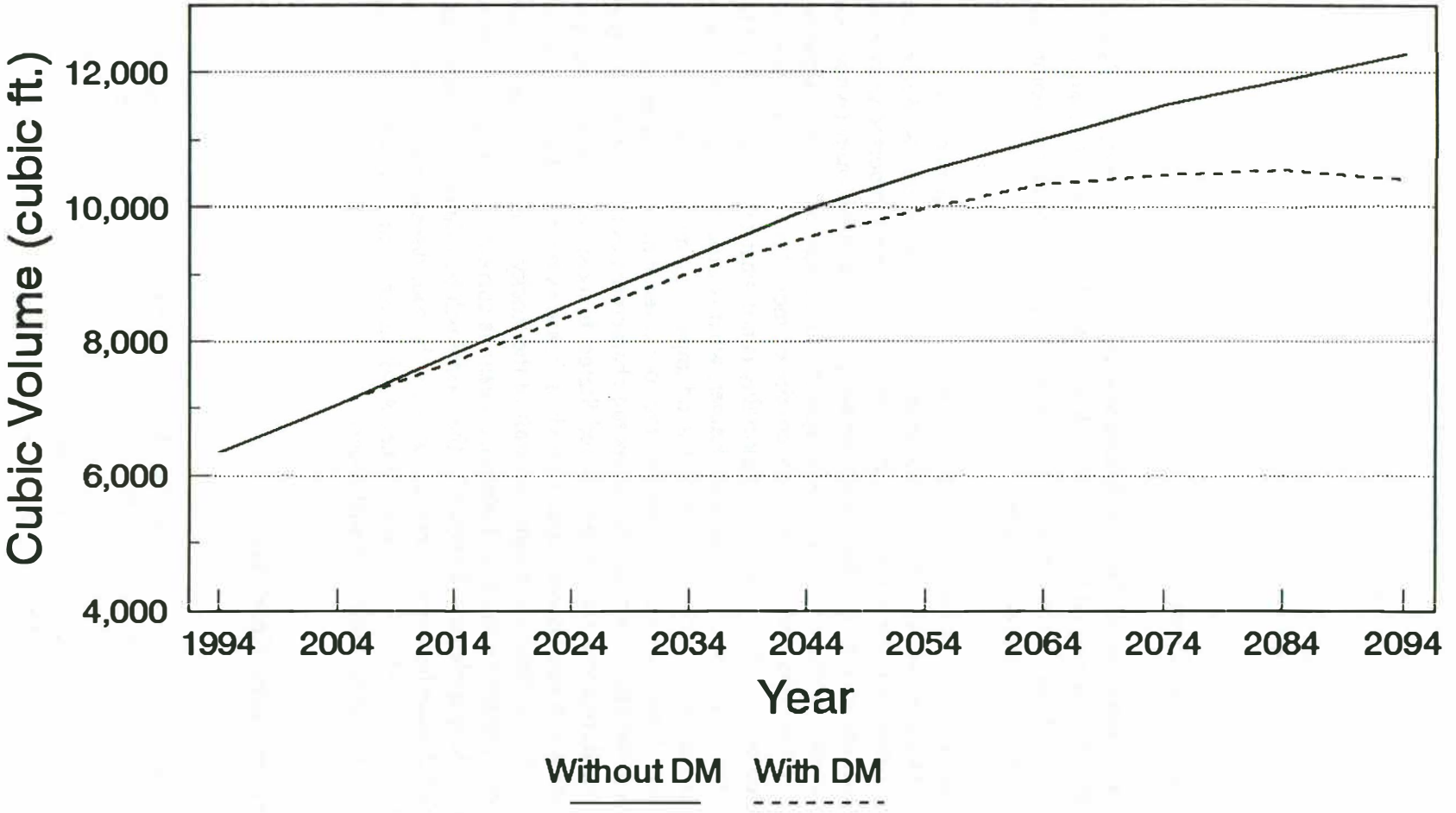
Stand 107004-10, High Mistletoe

Figure 16
STAND FVS RUNS - PINEY PROJECT
Impact of Dwarf Mistletoe on Cubic Volume



Stand 107001-11, Medium Mistletoe

Figure 17
STAND FVS RUNS - PINEY PROJECT
Impact of Dwarf Mistletoe on Cubic Volume



Stand 107303-18, Low Mistletoe

percent over the simulation period. The volume reduction was greatest in stands with the higher dwarf mistletoe ratings. In reality, all of these stands are currently near the recommended harvest age of 100-120 years, and thus should be scheduled for harvest in the near future. Those stands with the greatest amount of disease should be given highest priority for management activities in order to reduce future losses to the disease and reduce the potential for mountain pine beetle attack.

Armillaria Root Disease

Ten stands were chosen for root disease simulation runs. The percent of sample points with root disease ranged from 0-100% (low-high). A list of stands analyzed, together with starting stand age, percent of lodgepole pine, and percent of sample points with Armillaria root disease is presented in Table 13.

The impact of root disease on cubic volume over the 10-cycle period for three of the stands (High, Moderate and Low RD levels) is shown in Figure 18. While running the root disease model, it became evident that the impacts that were reported greatly overestimated the actual impacts of root disease on the sample stands. In all cases (where root disease was present), extensive mortality was reported for all age classes within the first 40 years. This was then followed by either slow continued mortality or slow recovery of the stand. As stated previously, this pattern of mortality is not what has been observed for lodgepole pine in the central Rocky Mountains. Rather, what is expected is greater mortality in the younger age and size classes, lessened stand impacts as stand age increases (over 25-30-years old). It must be kept in mind that the root disease model, as it presently exists, reflects assumptions on root disease spread characteristics that are true for the majority of situations throughout the western United States. In most cases, *Armillaria spp.* affects all size classes and cumulative impacts slowly increase as the root disease centers increase in size. The Forest Health Management staff of the Rocky Mountain Region, together with the Forest Health Technology Enterprise Team, is currently working on improving the model for lodgepole pine. Eventually, the model will be calibrated to better reflect observed disease behavior. However, because the root disease model runs do not currently reflect the expected behavior in the Piney Analysis Area, further computer analysis of future root disease trends was suspended.

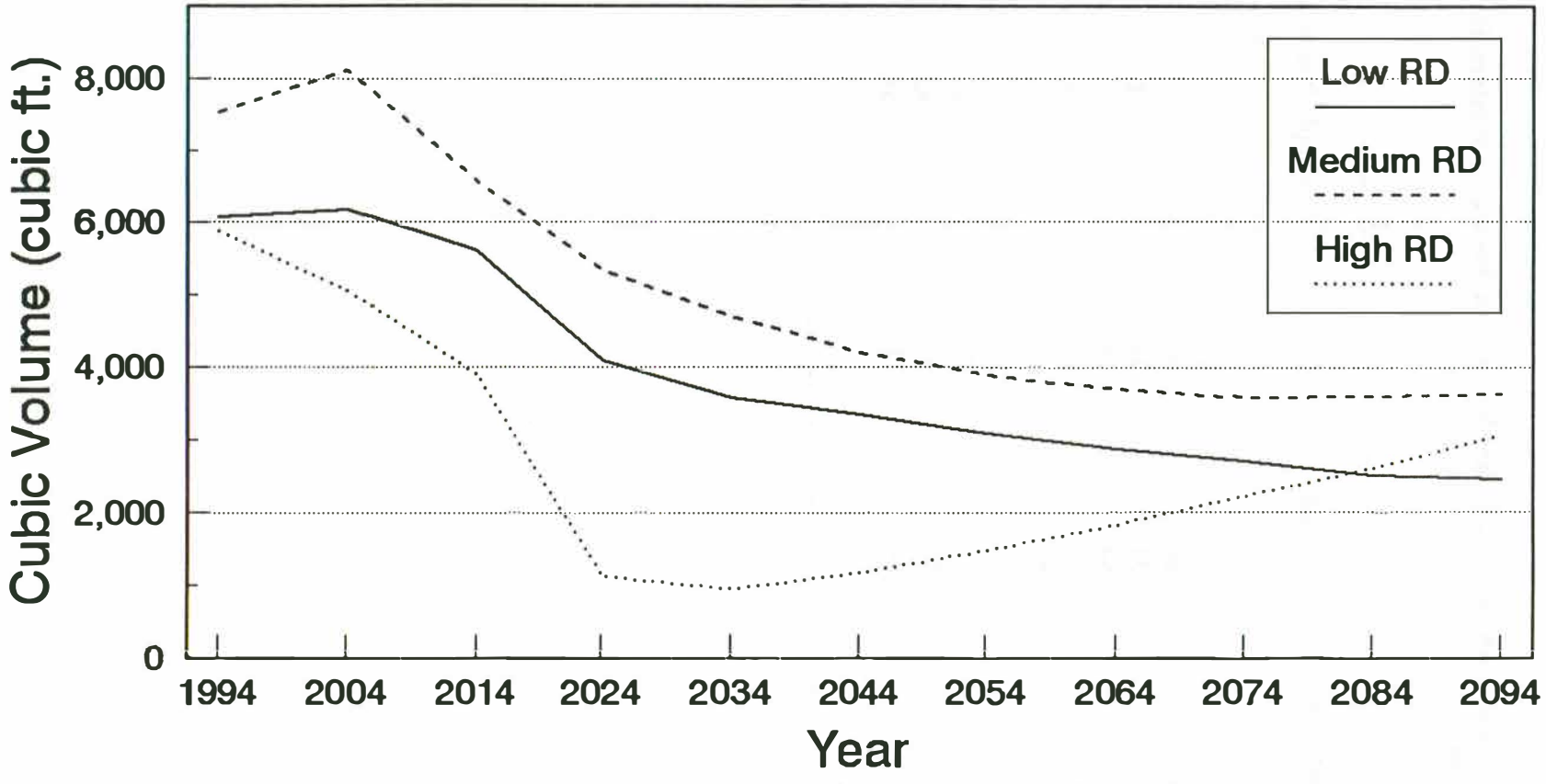
H. Desired Forest Condition

As mentioned in the Introduction, the Holy Cross Ranger District, including portions of the Piney Analysis area, has been the scene of past vegetation management activities. These activities were the direct result of a mountain pine beetle outbreak which began in the late 1970's and continued into the mid-1980's. An Environmental Assessment was prepared in the early 1980's to determine what methods to employ for control of the epidemic. The decision of then Forest Supervisor Woodrow in a signed Decision Notice

Table 13. Stands run through Forest Vegetation Simulator/Western Root Disease Model.

Stand identification	Stand age	LPP (%)	% Sample Points w/RD
101319-13	75	89	0
107303-18	84	89	0
107005-3	131	74	0
101306-4	84	76	17
107001-34	95	79	20
107004-10	126	93	20
107005-7	114	87	20
107302-8	99	77	40
101006-24	85	100	60
107001-7	64	51	100

Figure 18
STAND FVS RUNS - PINEY PROJECT
Impact of Root Disease on Cubic Volume



Low RD - Stand 101306-4
Medium RD - Stand 107302-8
High RD - Stand 107001-7

of October 28, 1981 was a combination of direct suppression, direct prevention, and silvicultural stand treatments on all lands except designated wilderness and wilderness study areas. Prescribed silvicultural treatments included regeneration harvests of mature, susceptible lodgepole pine stands and non-commercial and commercial thinning of lodgepole pine stands. The selected decision was to regenerate 33 percent of the susceptible lodgepole pine during the first entry period.

Individual Environmental Assessments were prepared for each timber sale resulting from the forementioned analysis and decision. Treatments began in 1984 and reached in peak between the years 1988 and 1993. Following is a summary of the regeneration harvests completed during that period:

Year	Acres Regenerated
1984	4
1985	0
1986	20
1987	46
1988	263
1989	145
1990	128
1991	188
1992	216
1993	139
1994	52

A total of 1,201 acres were treated during the period 1984 to 1994 to reduce the mountain pine beetle susceptibility in lodgepole pine within the Analysis Area. Treatments included 1,110 acres of clearcuts, 40 acres of overstory removal, and 51 acres of shelterwood seed cuts.

The Land and Resource Management Plan for the White River National Forest and Final Environmental Assessment for the plan determined a desired condition in terms of successional/structural stage distribution for forest types on the White River National Forest. This distribution is considered optimum for the Forest to provide a sustained yield of wildlife habitats, visual quality, dispersed recreation experiences, wood products, and resistance to insects and disease. Table 14 and Figures 19-22 compare desired conditions with existing conditions in the Piney Analysis Area.

As can be readily seen, the current structural stages for spruce-fir, lodgepole pine, and Douglas-fir are predominately in late and old growth classifications: spruce-fir (84%), lodgepole pine (84%); Douglas-fir (99%), and do not meet desired levels. To remedy this situation will take many years as stands grow into the next older structural stage and harvesting of late seral stages affords an opportunity to create younger seral stages. A balance needs to be found between the harvest of late seral stages and a decision to allow them to grow into old growth classes.

Table 14. Comparison of the WRNF desired forest condition with forest conditions at the Piney Analysis Area.[1]

	SUCCESSIONAL/STRUCTURAL STAGE [2]											
	EARLY[3/]			INTERMEDIATE[3/]			LATE[3/]			OLD GROWTH		
Forest Type	Age	Current Percent	Desired Percent	Age	Current Percent	Desired Percent	Age	Current Percent	Desired Percent	Age	Current Percent	Desired Percent
Aspen	0-30	3%	27%	31-70	69%	36%	71-100	27%	27%	100+	1%	10%
Douglas-Fir	0-40	0%	24%	41-90	1%	30%	91-150	84%	36%	150+	15%	10%
Lodgepole Pine	0-40	7%	30%	41-80	9%	30%	81-120	83%	30%	120+	1%	10%
Spruce/Fir	0-50	11%	32%	51-90	5%	26%	91-140	67%	32%	140+	17%	10%
Pinyon/Juniper	0-50	0%	30%	51-90	100%	24%	91-150	0%	36%	150	0%	10%

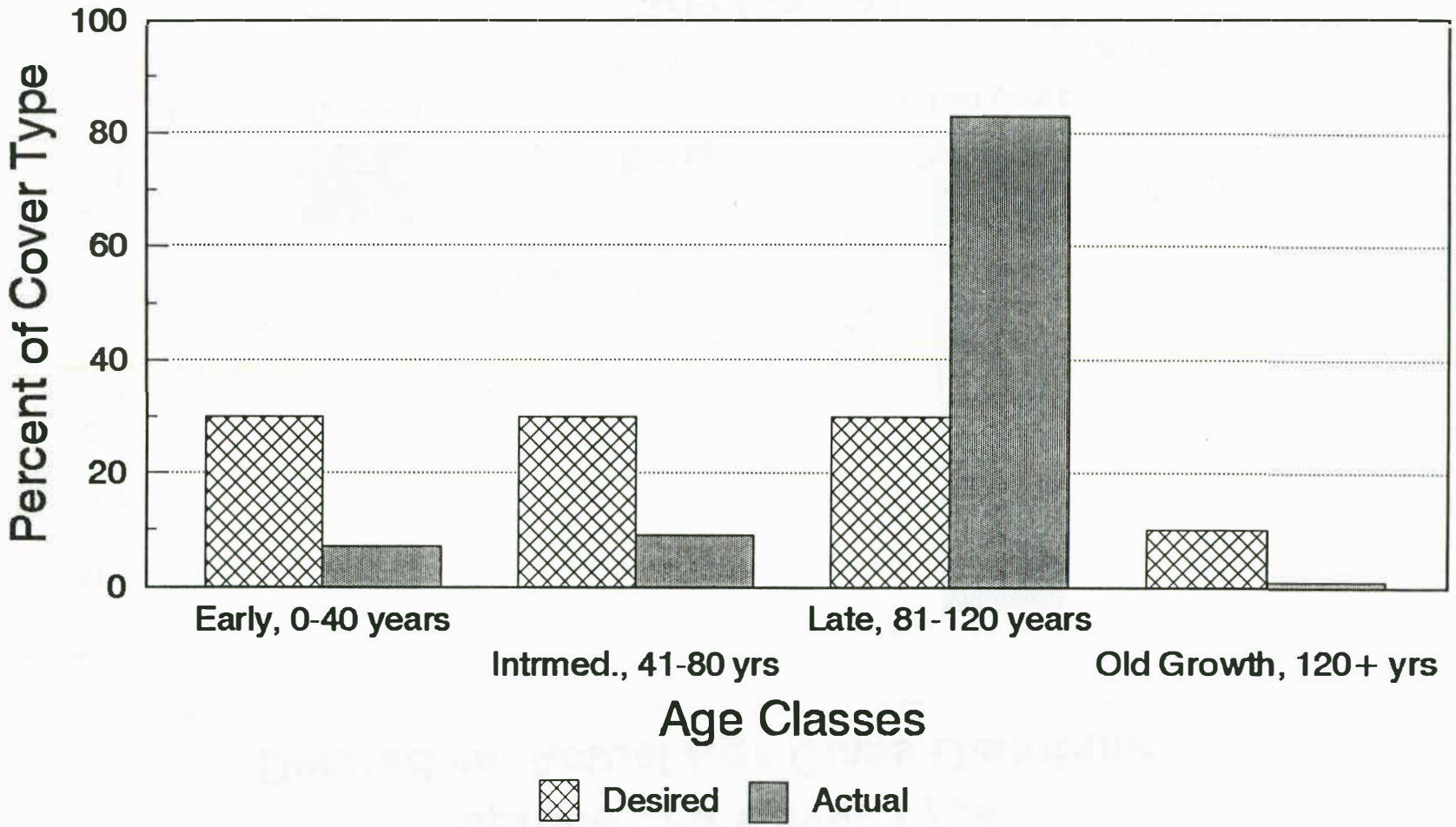
1/ The assumptions used in developing the "Desired" situation are shown in Appendix L of the EIS for the White River National Forest Plan.

2/ Successional/Structural Stage = Breakdown by age class (inventory for forested types - estimate for non-forested types). NOTE: Non-forested types (oak/mountain brush) are not found in the Piney Biological Evaluation area.

3/ Timber Vegetation Classification

EARLY 7 = Seedling - Sapling (trees 0" - 4.9" DBH)
INTERMEDIATE 8 = Pole Stand (trees 5" - 8.9" DBH)
LATE 9 = Sawtimber (trees 9"+ DBH)

Figure 19
Lodgepole pine Cover Type
Desired vs. Actual Age Class Distribution

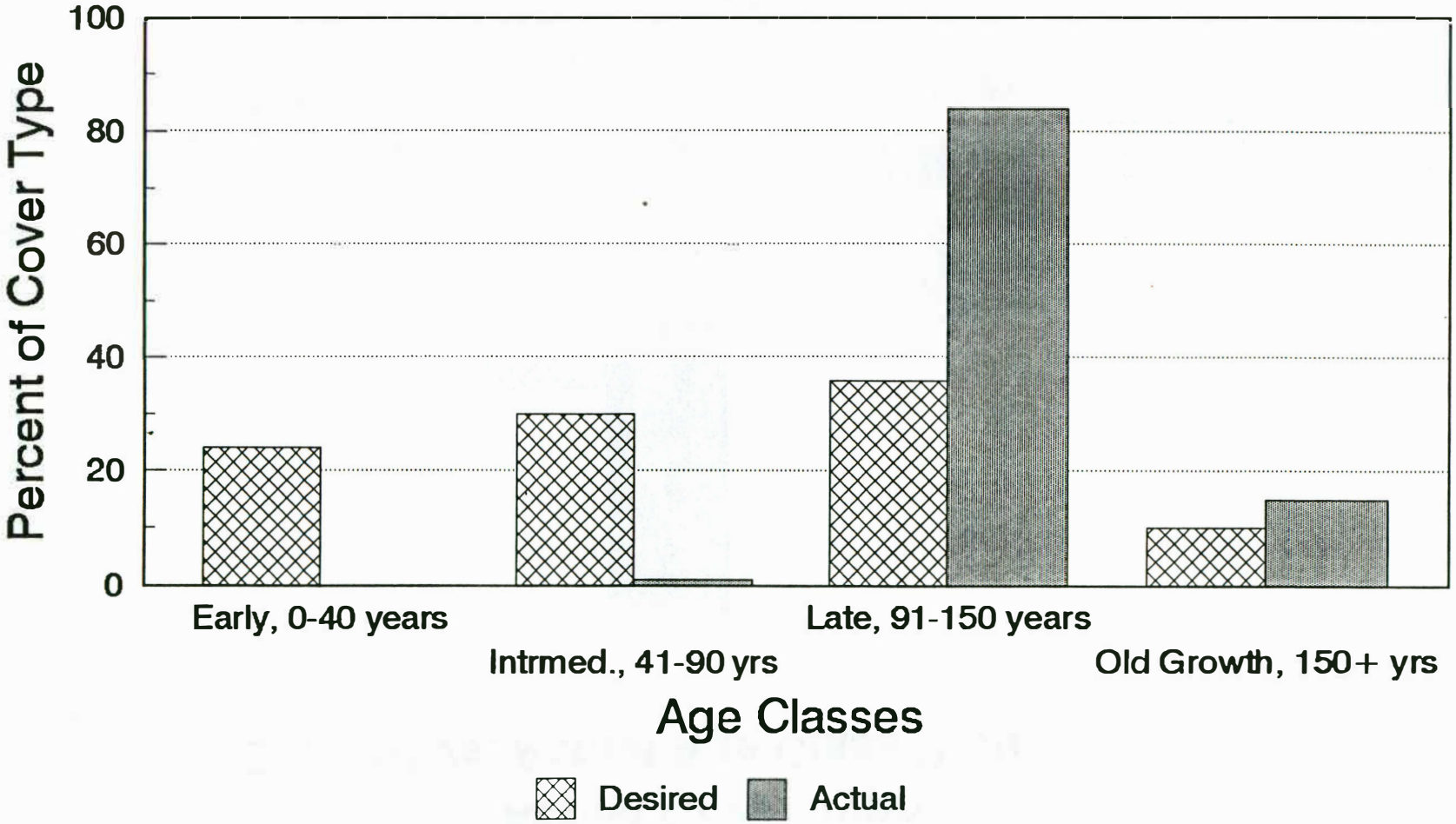


Piney Analysis Area - White River NF

Figure 20
Spruce / Fir Cover Type
Desired vs. Actual Age Class Distribution

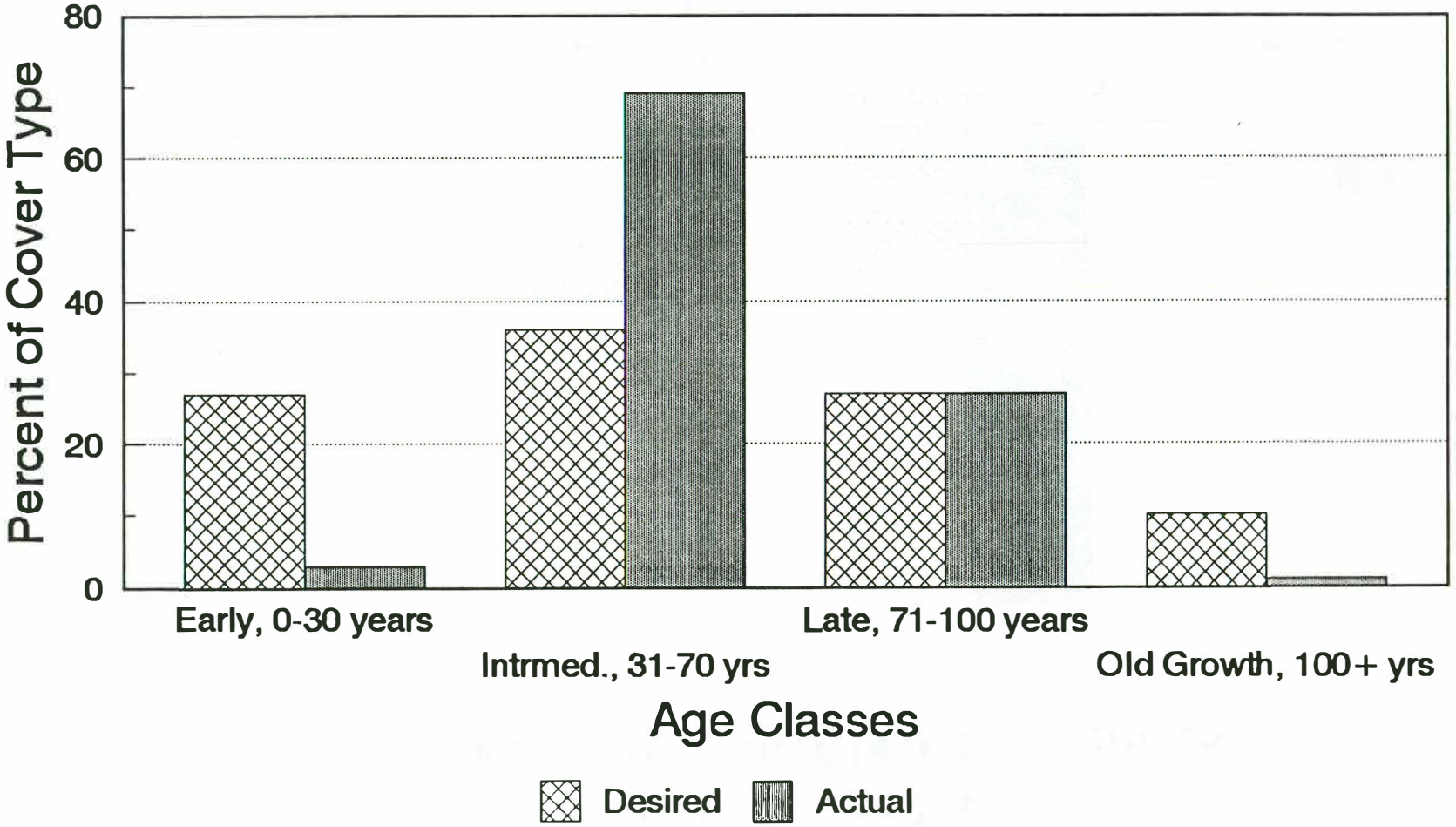
Piney Analysis Area - White River NF

Figure 21
Douglas-fir Cover Type
Desired vs. Actual Age Class Distribution



Piney Analysis Area - White River NF

Figure 22
Aspen Cover Type
Desired vs. Actual Age Class Distribution



Piney Analysis Area - White River NF